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SURFACE EFFECT CARRIER (SEC) STUDY. PART I. PLATFORM DESIGN.(U)

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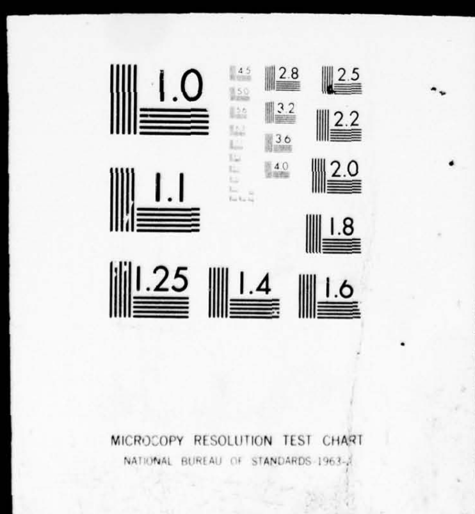

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Two versions of the surface effect carrier are designed to carry V/STOL aircraft. Gas turbines power one versity, lightweight nuclear power propels the other. (The key technical features of these designs are a high cushion length-to-beam SES hull and semi-submerged, supercavitating propellors.) Both vehicles are able to make 50 knots for 6,000 nautical miles and cost less to procure per aircraft carrier than a CVN. In addition, these platforms can be converted into a dry well amphibious ship capable of delivering a MAU.

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BY

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SURFACE EFFECT CARRIER (SEC) STUDY

PART I: PLATFORM DESIGN

EXECUTIVE SUMMARY

At the end of the Civil War, the Navy constructed its first steamship designed from the keel up for using steam propulsion. Previous steam plants had been installed in sailing ship hulls. The WAMPANOAG was large for her time (4200 T) and narrow-beamed (42.5' for a length of 355'); even with masts and spars (just in case...), she didn't look like a Navy ship. Though WAMPANOAG neatly passed her trials, attaining a speed of almost 18 knots in heavy seas, a "select committee" found her "a sad and signal failure...utterly unfit...too much of an abortion." The board commented that a steamship would be "a poor substitute for...the promptness and command found only on a sailing vessel."[1]

Times of radical change are always painful. The shift from sails to steam took decades and changed the talents required for ship building and operating from sails, wood and cordage to steel and steam. The U.S. Navy may now be entering just such an era of change. After fits and starts, we are procuring five more hydrofoil patrol craft and one 3000 ton surface effect ship -- designs that will permit us to "steam" at high speeds on (not in) the surface of the ocean. Again, there may be traumatic political and economic adjustments to

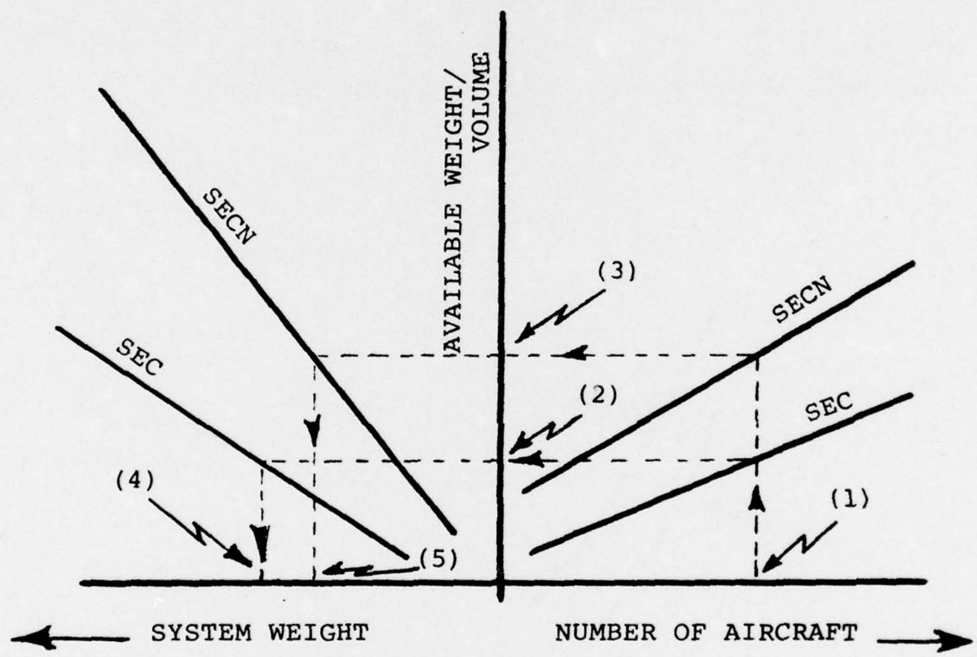
be made. Those who can build such vessels are not the traditional shipyards, but aircraft companies, such as Boeing, Lockheed and Rohr. However, the many benefits which may accrue from these new designs argue strongly for at least R & D in the field to determine the problems with and potentials of this new technology.

This study examines the logical utilization of a surface effect ship (SES) as a carrier for naval sea-based air power (circa 1990-2000). Part I (UNCLAS), contained in this volume, derives a conceptual design for such a carrier -- the SEC. Part II (SECRET) designs an accompanying surface effect excort (SEE), then synthesizes tactical insights of the benefits in operating battle groups composed of SECs and SEEs.

Cost effectiveness comparisons are neither very useful nor meaningful in examinations of futuristic technology. However, to ensure that we could afford an SEC, available cost models were employed to compare the estimated platform costs of the SEC and its nuclear-propelled variant, the SECN, against other designs considered by contemporary studies.[2] This was done for SEC/SECN designs carrying from 30 to 50 aircraft. The weight and volume requirements of these air wings were determined, then the minimum size SEC to support each was designed and costed. Combat suite weight and volume was held constant over that range.

After completion of weight and volume calculations for the SEC and SECN, a family of curves were derived for rapid conversion of air wing requirements to system weight. Figures 7a-7e on pages 38-40 show these results. One set of those curves would appear as follows for a selected cushion density and length-to-beam ratio:

FIGURE ES-1a
DESIGN CURVES



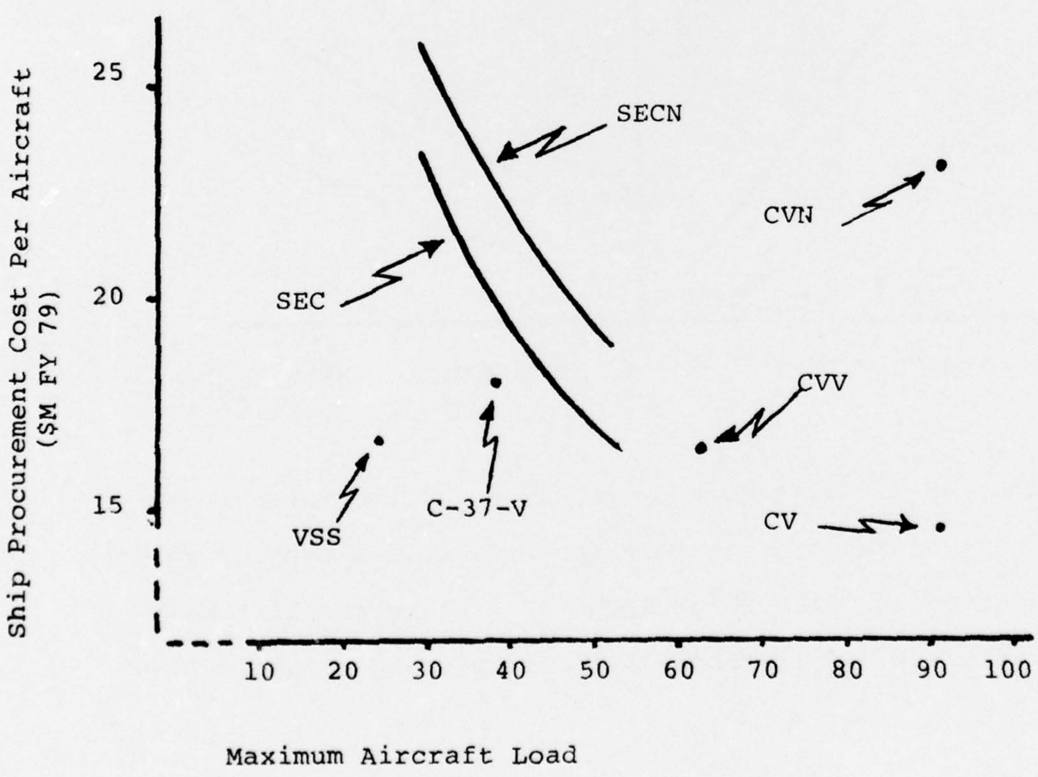
The desired air wing size is selected (1) and the curves to the right employed to show the available weight or volume provided by the SEC (2) or SECN (3). Using the left half of these figures permits translation of payload weight/volume

into minimum system weight ("displacement") for the SEC (4) or SECN (5). Conversely, the curves can be used from left to right to determine maximum air wing size.

The results of that analysis, shown in Figure ES-1b, reveal that these designs become cheaper than a CVN at deckloads above 32 (SEC) to 38 (SECN) planes and that the SEC is competitive with a CVV if sized to carry about 50 planes.

FIGURE ES-1b

AIRCRAFT CARRIER COSTS PER AIRCRAFT EMBARKED



The relative positions of the curves shown above are consistent for all combinations examined herein. While the SECN is more expensive per aircraft carried, it is obvious that there is a marked advantage for nuclear powered designs over those using gas turbines. In every case, the SECN could support a given air wing with a smaller ship than could an SEC design. At any given displacement, more aircraft could be supported if the ship had nuclear propulsion. This fact, combined with the unlimited endurance of the SECN, constitutes the strongest possible argument for development of lightweight nuclear propulsion plants to complement SES technology. The increased flexibility and capability that LWNP would add to SES (and to displacement hull designs as well) are obvious benefits that should not be ignored.

To attain further comparability by being able to equate air wing costs between two sets of platforms, an SEC design to support 45 aircraft was selected. Hence, two surface effect carriers could support the same number of aircraft as could one of today's CVNs.

The technology incorporated in this conceptual design was derived from that employed in the recent Advanced Naval Vehicle Concept Evaluation (ANVCE) Study. Technical features found to be of chief importance in attaining the desired 6000 nm endurance at 50 kt were:

- A high length-to-beam ratio (5-7) to reduce drag in the 30-60 kt range over current designs whose ratios are about 2-3.

- Electrically driven semi-submerged supercavitating propellers for more efficient transmission of energy to speed.
- For the SECN, the development of a Lightweight Nuclear Power Plant (LWNP).

An artist's concept of the SEC resulting from this design is shown in Figure ES-2. Figure ES-3 provides, for comparison, SEC flight decks alongside those of a VSS, CVV and CV/CVN. Table ES-1 compares their characteristics in greater detail. It can be seen that the surface effect designs are much lighter than the displacement hulls and capable of about twice their speeds.

In order to provide impetus to R & D on V/STOL aircraft, the Navy has stated its plan to convert to V/STOL from the catapulted/arrested CTOL planes currently in use. The SEC is designed to operate a notional V/STOL with characteristics similar to current V/STOL A proposals. However, with its 6^{o} bow ramp and high wind over deck generated by speeds of 40-50 kt, this ship can handle CTOL as well -- and with no catapults and possibly lighter arresting gear than found on today's carriers.

A brief analysis examined the SEC/SECN in an amphibious role. Its findings were of such interest that modifications were designed for such an adaptation. Utilizing Roll On/Roll Off (RO/RO) cargo handling facilities and container "vans"

FIGURE ES-2

SURFACE EFFECT CARRIER
ARTIST'S CONCEPT

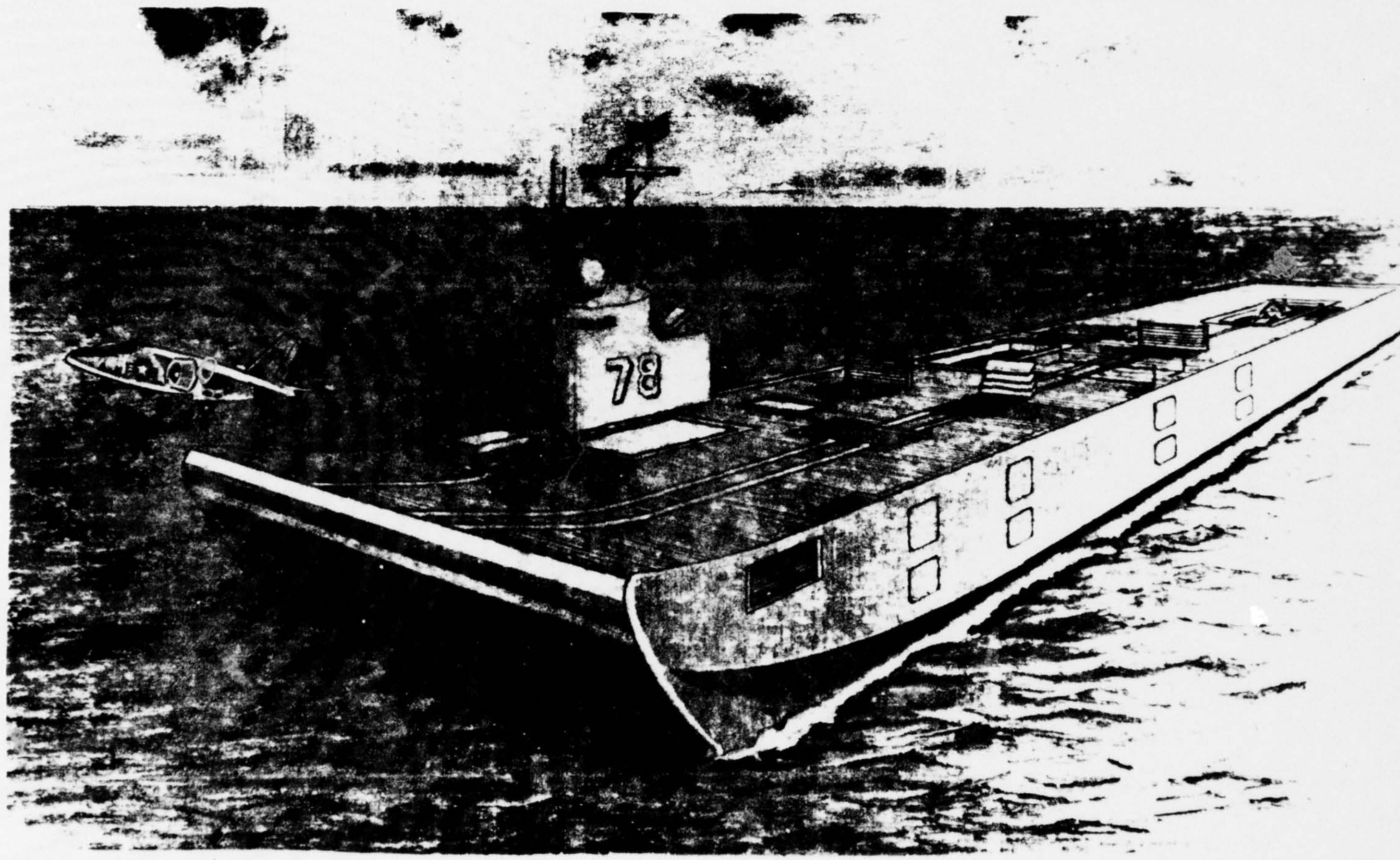


FIGURE ES-3

CARRIER FLIGHT DECKS

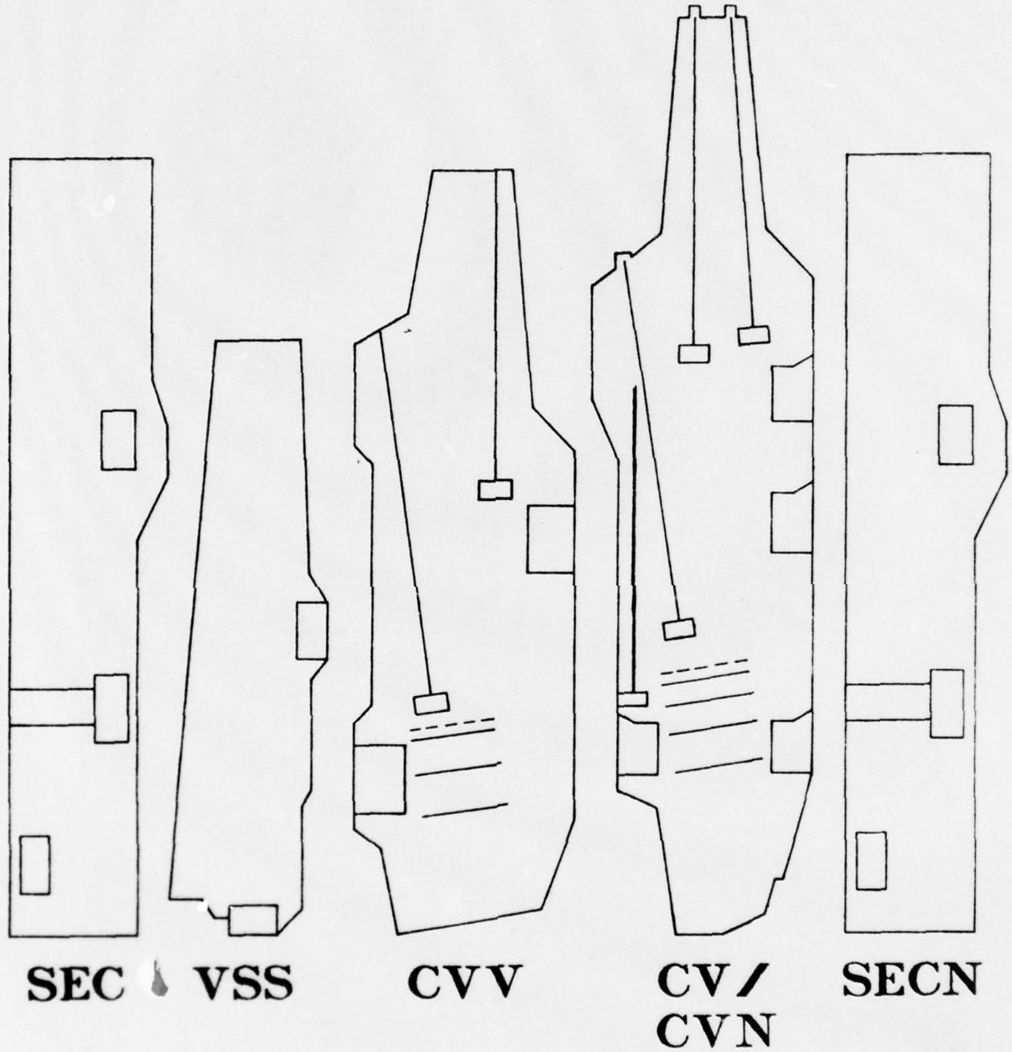


TABLE ES-I

SUMMARY OF CARRIER CHARACTERISTICS

	CVN	CV	CVV	VSS	SEC/SECN
Displacement/ System Weight (kmT)	98	84	64	24	26/22.5
Length (m)	333	315	275	200	278/279
Beam (m)	82	82	82	30	50
Height (m)**	19	19	18	16	26
Speed (kt)					
Endurance	20	20	20	20	40/50*
Max. Sustained	30	30	26	28	55/50
Elevators	4	4	2	2	3
Catapults	4	4	2	0	0
Arresting Wires	4	4	3	0	2
CTOL?	Yes	Yes	Yes	No	Yes

*At 50% Fuel Loading.

**Flight Deck to Waterline

for combat cargo, shops, and even some berthing, the SEC/SECN becomes a capable amphibious support ship. One SEC can accommodate a notional Marine Amphibious Unit (MAU) with 1800 men and their necessary landing craft, helicopters and support vehicles. While it could not handle displacement landing craft, it could operate current wheeled or tracked amphibians and the future air cushion designs, such as the LVA and LCAC,

It would also retain 12 V/STOL for self protection and/or close air support. An SECN so modified would retain 16 aircraft for these missions.

In summary, surface effect technology can provide unique capabilities to the U.S. Navy. While the designs herein are conceptual and will require revisions and refinement as the technology matures, it is obvious that the potential benefits warrant funding the RDT&E necessary to pursue it. Surface effect technology may accomplish for the surface Navy what steam and steel accomplished a century ago.

PREFACE

The author of this study is an engineer attached to the David Taylor Naval Ship Research and Development Center (DTNSRDC) at Carderock, Maryland. During the latter part of of 1977 and the early part of 1978, he was assigned as a student at the Naval War College and selected for sponsorship by the College's Center for Advanced Research. He first formulated the conceptual design for an SEC, as described in this volume, then participated with several naval officers in a group project which derived tactical concepts for SEC task groups. Tactical concepts are described in Part II, published separately.

While the opinions, assertions and conclusions expressed herein are, of course, those of the author, a debt of gratitude is owed to many organizations whose cooperative support made this project possible. Besides the Center for Advanced Research which provided critical monetary, administrative and moral support, the study could not have been accomplished without the assistance of the Office of the CNO (OP-03, ANVCE Project, and OP-095), the Naval Sea Systems Command (PMS-304), the Naval Ships Engineering Center, the Center for Naval Analyses, Westinghouse, HQMC (Amphibious Ships Requirement Branch) and DTNSRDC.

The following work was derived from the SES Performance Routines, developed and maintained by Code 163 of DTNSRDC. All platform performance information employed in the design method and presented in this report was obtained from this source. However, the design method was not created for a parametric design study, but sought to produce designs similar to the ANVCE point designs. ANVCE guidelines were followed, except for changes that are noted in the text. The designs are not nearly as detailed as the ANVCE efforts, but could easily be upgraded to that level if sufficient expertise in areas such as structure, propulsion, and auxiliaries was made available.

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CHAPTER I

INTRODUCTION

Background

For 40 years, the acknowledged cutting edge of naval power has been sea-based air. It has permitted the U.S. Navy to assure maritime superiority wherever necessary, as spelled out in its mission.[1] Today, the threat posed by Soviet nuclear and conventionally armed cruise missiles, the size and paucity of floating bases to provide this air power and the demands of economists to do more with less, are stimulating a continuing examination of the means for assuring maritime air superiority in the future. V/STOL aircraft designs are being evaluated. These will provide land/launch capability from decks that have been damaged and from smaller ships dispersed over a larger area. Remotely-piloted or guided power projection may accrue from research in the cruise missile field. For many scenarios, however, the need will remain for manned aircraft, forward-deployed at sea, and the complex capable carriers which are needed to support their round-the-clock reliable operations.

This study was performed to examine an option for forward-deployed sea-based air power which offers increased platform survivability with high mobility and flexibility and, perhaps, without requiring the penalty to TacAir unit capability that must be paid with V/STOL. Tests with 100T surface-effect ships (SES) have proven the feasibility of these high-speed vehicles under conditions suitable to their size. The recently funded 3000T SES (3K SES) prototype will examine the practicability of surface effect technology in an ocean-going design. The following pages take a major step beyond the 3K SES to develop a conceptual design for a Surface Effect Carrier -- the SEC. Volume II of the study (SECRET) develops tactical concepts and insights for employing the SEC. Herein the effort has been constrained to concept formulation and design of a platform which could serve in either the sea control or amphibious projection roles now assigned to the U.S. Navy against the threat postulated for the 1990s when such a ship might enter the fleet.

As with any new development, some technical risk is associated with various components of this design. This is specifically pointed out through the study. Additionally, since the study focuses on hardware design, costing may appear optimistic to the skeptic. Two factors should be considered in this regard. First, were an extremely precise costing model to be stated, its validity would still be in

question at this stage for a platform to be procured 10-15 years in the future. Secondly, if cost effectiveness had always been our only measure of the value of innovation, we would still be sailing before the wind. There would have been nothing appealing to the economists (or the environmentalists) in converting from sails to steam -- it was merely a matter of survival.

Rationale

Applying SES technology to the missions of an aircraft carrier seems to form a natural union. The SES requires a low-density payload, since its weight-carrying capability per unit volume is limited by its technology. Carrier missions require storage space for aircraft at a minimum weight, because the weight of the platform is directly related to its procurement and operating costs.

A carrier must be able to move aircraft where they can be effective and to withdraw when advisable. The SES can carry out these maneuvers with greater mobility since it has an endurance of 6,000 nm at 50 knots when powered by gas turbines. The nuclear-powered SEC, the SECN, has a 50 kt capability for up to ten thousand hours or about half a million miles.

SES carriers will be able to carry more aircraft per ton than displacement hull designs due to the low density of the SES hullform. The weight, or displacement, of a ship

affects its cost. If these platforms can be produced for a cost that will permit two to three SECs, together carrying the air wing of a CVN, to be obtained for no more than the cost of the CVN, then the faster and more numerous SEC platforms could operate over a greater portion of the world's oceans than could slower and fewer carriers. The CVN, which can be trailed by surface and subsurface units, is both a tempting and targetable concentration of force whose early loss would irrevocably alter the balance of power in a war. In contrast, several smaller carriers, embarking the same air strength, and whose speed prevents trailing by all but aircraft and satellites, can be dispersed to complicate preemptive destruction by an enemy.

The SES design also seems suitable for conversion to an amphibious assault ship having both landing vehicles and helicopters. The landing vehicles would be restricted to those which do not need a wet well deck, such as the Landing Craft Air Cushion (LCAC) and Landing Vehicle Assault (LVA). To create this capability, the SEC need only be designed with a roll-on/roll-off hangar deck to allow for the rapid movement of landing craft as large as the LCAC. The SEC can operate at various immersion levels by altering cushion pressure, thus permitting the disembarking of landing vehicles. Such operations would be at speeds below 20 knots. This conversion capability should not diminish the vehicle's performance as a carrier. The advantage of

procuring a single platform that can be used as both a carrier and an amphibious assault ship should be significant.

CHAPTER II

SEC DESIGN METHODOLOGY

The SEC, in common with displacement hull carriers, can be treated as a system with three components. First, there is the platform with its requirements and capacity, then the organic combat suite, and finally the air wing. In design of the platform, two parallel sets of calculations must be made, one to compute the weight each design can support for a combat suite and air wing, and the other set to monitor its volumetric capacity. Surface effect designs are unique in that platform characteristics are also dictated by platform weight, cushion density and cushion length-to-beam ratio.

For this analysis and conceptual design effect, air wing size was varied independently from 30-50 notional aircraft and the combat suite was held constant over that range. The platform designed was the minimum size that could meet the weight and volume requirements of the various air wings and the combat suite. The term 'system weight' (W), as used herein relates to the more familiar term 'displacement', which is applied to conventional hulls.

Air Operations Requirements

In addition to weight-carrying and volume capacity for embarked aircraft, the SEC must be configured to launch,

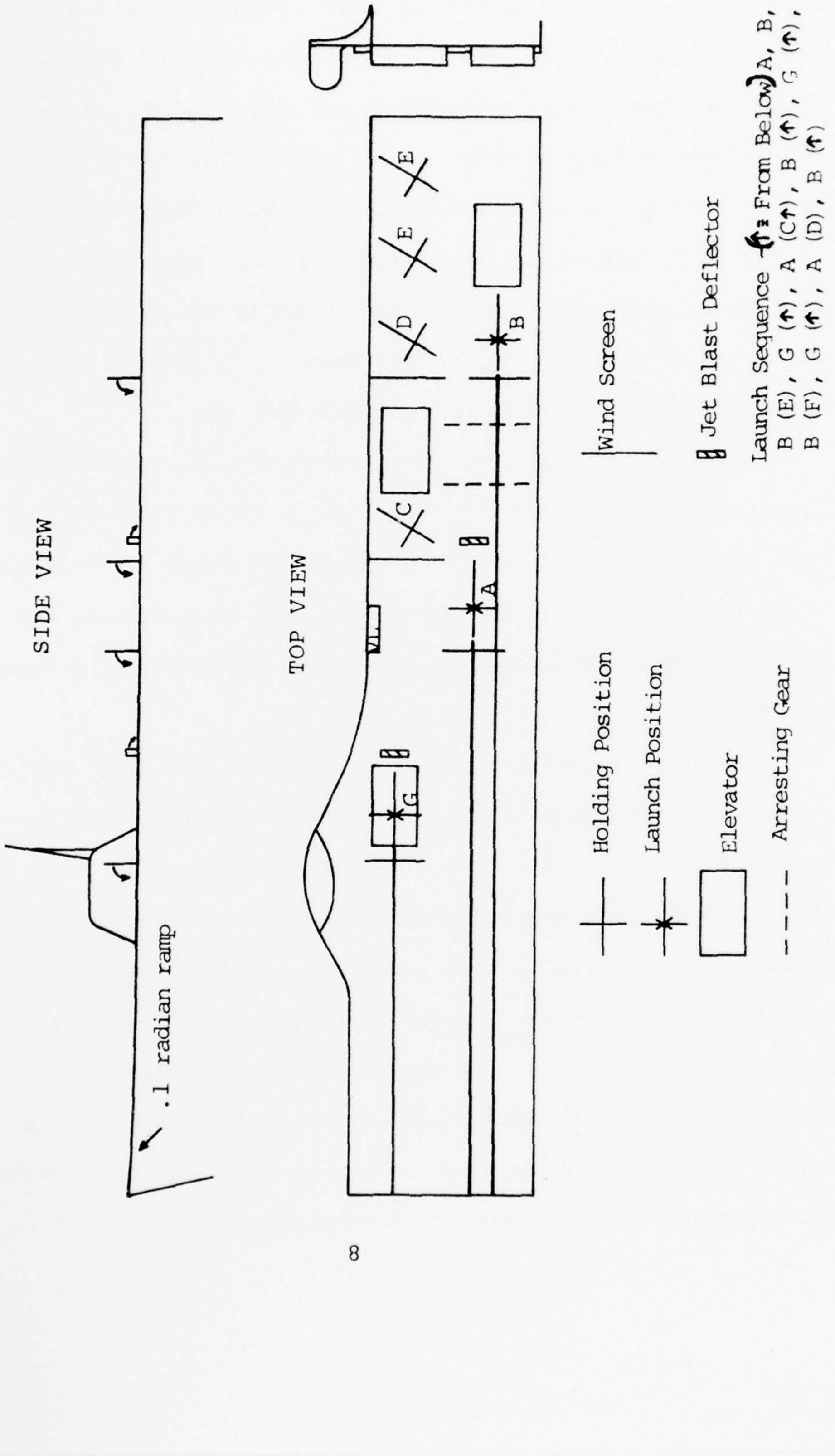
recover, and service aircraft within the ship. The flight deck arrangement will handle both Vertical/Short Takeoff and Landing (V/STOL) and Conventional Takeoff and Landing (CTOL) aircraft. It was optimized for V/STOL, since present Navy plans are to convert to an all-V/STOL force in the 1990s. CTOL was included to permit some flexibility with assets that may still be in the fleet at the time an SEC may be introduced. A CTOL-only version of an SEC would require a redesign of the flight deck for optimization and might result in different platform designs.

The flight deck, as shown in Figure 1, consists of a long portside runway (>180 m) from which both V/STOL and CTOL aircraft (e.g., the F-14 or F-18) could be launched. (A 50-knot wind over the deck (WOD) is the minimum WOD for such launches and is always available from the platform's own speed).

Two arresting barriers or wires are provided for CTOL landing on the central runway. They overlap both the port and starboard runways. The center runway can be used for takeoff and landing without disturbing the ready spots of the other two. The launch position of this runway, labeled A on Figure 1, cannot be occupied during launches from the port runway, spot B. The short starboard runway from the forward elevator has a minimum length of 65 meters and its launch spot, G, can have an aircraft in place while launches occur on the other runways. A central runway launch

FIGURE 1

SEC FLIGHT DECK LAYOUT



requires the aircraft at launch spot G to have its wings folded. Normal operations would consist of alternate launches from A and B with ready position, C, as checkout position for launch spot A. Ready spots E, E, and F are available for holding malfunctioning aircraft or staging for large attacks.

Each ready or launch spot is equipped with an air-conditioning unit; A and G are equipped with jet blast deflectors to protect the area aft of these positions. These deflectors are a new design that incorporates turbine blade technology to reduce size, weight, and auxiliary load requirements. The deflectors direct the blast to the side rather than up. No reports are available, but experiments are under way on these deflectors. The deflector's weight is speculative and based on expected reduction in size by two-thirds of present deflectors.

Wind screens to protect personnel, aircraft, and handling equipment are required to conduct flight deck operations with WOD of 50 kt and higher. The height of the screen will need to be about eight meters to cover the folding of helicopter rotors and will average about 20 meters in length with a porosity of 50%.[1] Assuming that aluminum channels (depth = .38 m, width = .09 m, thickness = .01 m) would make up the vertical members and the three horizontal stiffeners of these screens, the actual fence

would weigh five metric tons which is increased by 50% for structural supports to hinge the screen to the deck, and 2½ mT for the mechanisms to raise and lower the screen. The total weight of the screens, including division into Ship Work Breakdown Structure (SWBS) groups, is shown in Table I, along with other equipment related to the air wing.[2]

TABLE I

AIR WING SPECIAL EQUIPMENT

ITEM	NUMBER	WEIGHT (mT)	SWBS GROUPS 100 (mT)	500 (mT)	15% MARGIN (mT)
Elevator	3	675	195	480	101
Arresting Gear	2	90	10	80	14
Jet Blast Deflector	2	70	58	12	10
Wind Screen	5	50	37	13	8
Air Conditioner	7	11		11	2
TOTAL WEIGHT		896	300	596	135

The final feature of the SEC flight deck is a 6° ski jump or ramp at the bow. This British concept has been tested with the Harrier. Calculations at DTNSRDC indicate that at maximum takeoff weight, an F-18 would need only a

100 meter deck run to launch with this ramp at 60 kt WOD. However, the ramp was included in this design as a safety feature and to add flexibility. The ramp would give any pilot losing power at the end of the runway an extra second or two to eject. It can be removed from the design if it proves to cause more problems by generating air turbulence than it solves in safety. No special weight allowance was considered necessary for the 28 meter ramp.

V/STOL landings will be vertical, with spots aft of the two forward elevators as the best sites. From these positions, aircraft can taxi forward or be towed to the nearest elevator forward of the landing position. In an emergency, aircraft could land anywhere on deck; however, moving aircraft to elevators may require the ship to reduce speed. The island mast should provide pilots a visual reference for their vertical landings. Note that the CTOL landing site is beside the middle elevator, over 70 meters from the stern. The middle elevator is not in the CTOL landing runway, but should be in an up position during CTOL landings for safety.

Elevators are sized (21 m x 12 m) to handle as large an aircraft as the F-14 with a tractor (90 mT). Elevator weight is estimated based on examining existing carrier elevators and those proposed for the Sea Control Ship. SEC elevators differ from most of these elevators in that they

are inboard rather than at deck edge, must travel to two hangar deck levels rather than one, and are aluminum rather than steel. The elevator, like other equipment, will need R&D, but is not beyond today's technology to produce for the approximate weight estimates shown.

Below Decks Air Wing Requirements

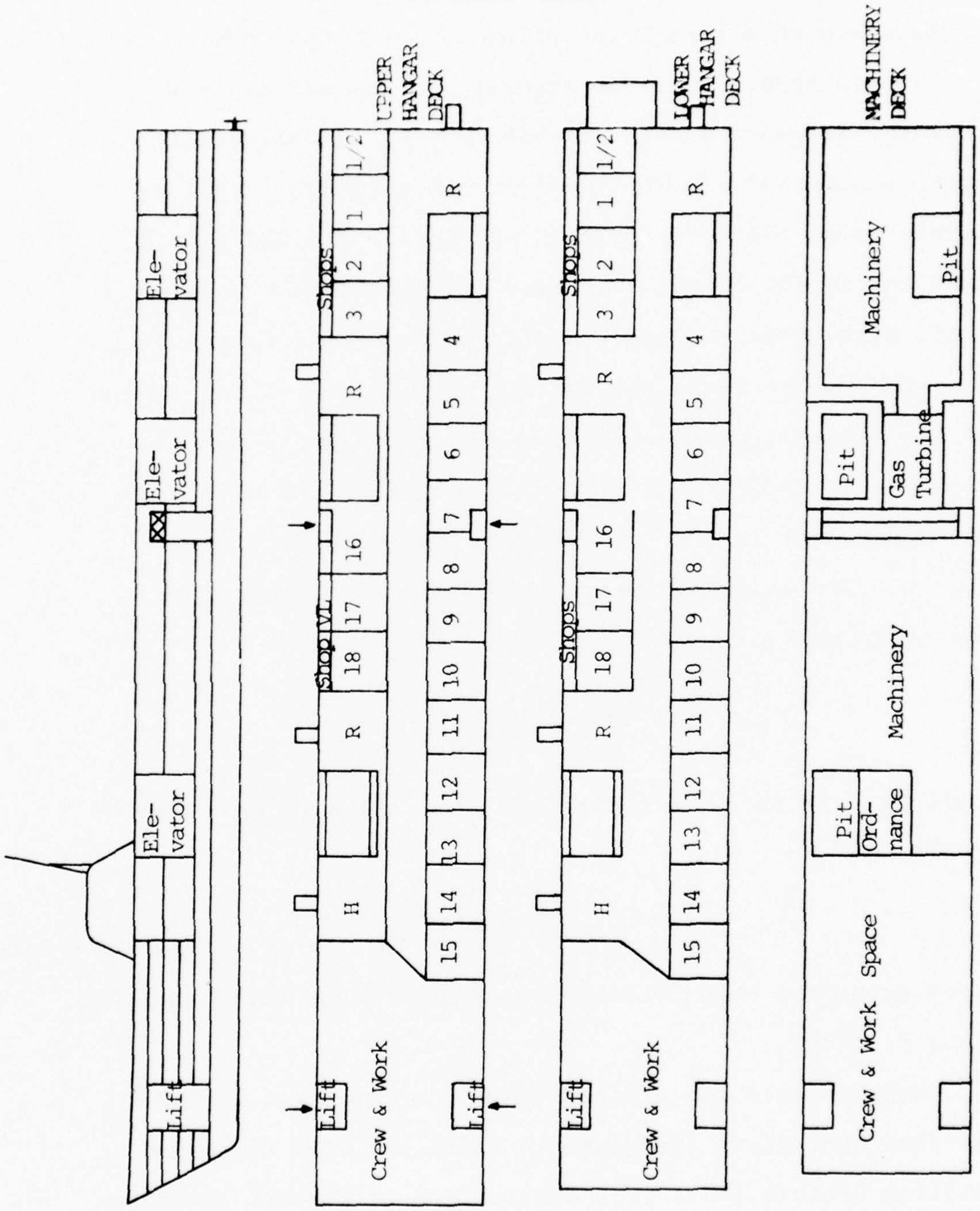
The elevator delivers aircraft to and from the flight deck and the two hangar decks. The SEC cannot retain aircraft parked on the flight deck for sustained periods of time since certain combinations of high winds and ship maneuvers might cause damage .

The SEC is required to have volume to stow all its air wing below the flight deck. This causes the SEC to have two levels of dual hangar decks as shown in Figure 2. If the SEC carried less than 30 aircraft, a single hangar deck would be sufficient.

The hangar deck has a single aisle with parking rows on either side. The aircraft is parked at an angle to the centerline of the ship facing aft. Although an aircraft's nose will overlap the next one, each aircraft can be removed without disturbing any other. One-meter clearance is allowed around each. Three aircraft are kept at ready position behind each elevator on each level. A fourth aircraft is parked forward of the forward elevator when all aircraft

FIGURE 2

SEC INTERNAL LAYOUT



are stowed. This spot is emptied when any aircraft is on the flight deck or in the air, since this spot is necessary to turn around aircraft returning to the hangar deck.

The standard spot for aircraft on the SEC is 15 m x 14 m; it would accept an F-18 or S-3, as well as all but one proposed V/STOL A design. This space is approximately twice the required A-7 deck spot. The SEC should have sufficient hangar deck area for some growth in aircraft size beyond a V/STOL A with its spotting factor of 1.3.

The hangar decks require the most volume of any portion of the system. These decks are assumed to be 42 m wide, with the lower deck 7 m high to accommodate the LCAC, and the upper deck at 6 m, the height of our new carrier designs.[3] The length of hangar decks, l_h, is computed by the equation:

$$l_h = 50 + (3.75)\, N_{A/C}$$

where $N_{A/C}$ is the size of the air wing. Similarly, total volume is:

$$V_h = 27{,}300 + (2047.5)\, N_{A/C}$$

These equations were derived from Figure 2 and verified by later results.

Requirements for aircraft-handling equipment, spares, and shop containers are given in Table II. The Universal Handling Vehicle (UHV) is a combination of present spotting

dollies and a tow tractor now under development. It will fit beneath an aircraft, turn it around within its own fuselage length, and carry an air starter and an electrical generator. For every two UHVs required to move aircraft, a third will be equipped to fight fires. These vehicles will be parked under aircraft when not in use. Sealed versions of UHVs will be used on the flight deck for safe operation in high relative winds.

TABLE II

AIR WING HANDLING EQUIPMENT

ITEM	WEIGHT (mT)	A/C PER ITEM	WEIGHT PER A/C (mT)
Crash Crane	57	Air Wing	-
UHV	6	3	2
Fire Fighting UHV	7	6	1.2
Skids, Chocks and Tie Downs	0.3	1	0.3
Shops & Spares Container	4	1	4
TOTAL			7.5

The crash crane will be stored under the island when not in use. Skids to move ordnance between the aircraft and the magazine, aircraft tie downs, and chocks are

included in the support suite. Shops and spare parts will be prepackaged in standard containers (2.5 m x 2.5 m x 6.5 m or 8' x 8' x 20') to facilitate loading and unloading. These containers can be secured two levels high around the hangar decks. Certain parking areas will be designated as special shop areas, permitting major repair work to be conducted near an appropriate shop. This container concept is based on the Marine Corps usage of such a system.

The SEC carries nominal V/STOL aircraft with the characteristics shown in Table III. For comparison, the table also shows the characteristics of a typical V/STOL A, the F-18, and two LAMPS MK-III helicopters. Note that all four (treating the two LAMPS as a single vehicle) are similar. Since this study was directed at designing a carrier platform, not an air wing, its approach was to simplify the aircraft in the wing to a single set of notional characteristics. This aircraft is a composite of the other aircraft of Table III and is representative of the future V/STOL in the U.S. Navy.

An expendable loading of 6 tons of fuel and 3 tons of ordnance per sortie is assumed, of which 1 ton of fuel and .2 of a ton of ordnance will be recovered. The former represents an 18% fuel reserve, the latter some unused expendable sensors. The nominal V/STOL is expected to be available 70% of the time to fly one sortie per day for 15

TABLE III

SELECTED AIRCRAFT CHARACTERISTICS

	NOMINAL V/STOL	TYPICAL V/STOL A	F-18	TWO LAMPS MK-III
Empty Weight (mT)	16.0	14.0	13.0	9.9
Folded length (m)	17.0	17.0	17.1	18.0[b]
Folded Width (m)	8.0	8.0	7.6	8.0[b]
Folded Height (m)	5.0	5.0	4.5	5.1
Fuel Capacity (mT)	6.0	5.0	7.3[a]	5.5
Ordnance Capacity (mT)	6.0	6.0	6.2	1.5

[a]Includes 2.3 mT of fuel in external tanks.

[b]Based on two helos parked side by side, a meter apart, and one advanced a meter so that the tail surfaces do not touch.

operational days. These assumptions lead to the expendable requirements shown in Table IV. The SECN is assumed to have one-third more operational days to take advantage of having no need to refuel. Further, the SEC can share its fuel with embarked aircraft which the SECN can not.

The volume allotted for air wing ordnance is 150% of the volume required if the ordnance consisted solely of

TABLE IV

EXPENDABLES PER EMBARKED AIRCRAFT

	WEIGHT (mT)		VOLUME (m^3)	
	FUEL	ORDNANCE*	FUEL	ORDNANCE*
SEC	52.5	29.4	70.9	37.3
SECN	70.0	39.2	94.5	49.8

*Includes expendable sensors.

Harpoons. Most air-deliverable missiles, except Phoenix and Maverick, have an equal or greater density than Harpoon. This volume should permit sufficient space for storage and allow for future growth. Air wing fuel is provided a 10% greater volume than required for its weight. Table IV also gives the volume requirements of the air wing's expendables that for safety will not be stored on the hangar decks. This ordnance will be placed in magazines on the machinery deck. Munition elevators will bring ordnance to each hangar level. Weight and volume of the fueling system and munition elevators are included in platform auxiliary weights.

Twenty-five personnel are associated with each aircraft to fly, staff, and maintain the plane. This assumption is based on current personnel requirements. Manning impact on the design is shown in Table V. These allowances

TABLE V

AIR CREW REQUIREMENTS PER AIRCRAFT

SWBS GROUP	WEIGHT (mT)	VOLUME (m^3)
500	2.5	--
600	3.75	545*
Margin	.94	--
Crew Load	9.5	--

*Personnel volume covers both group 600 and crew loads.

for the crew are based on empirical relationships accounting for the auxiliary and outfitting needs of each person aboard. The number of wing-associated personnel is larger than the ship's company and is a major factor affecting the design.

The preceding descriptions of the air wing, flight deck and hangar decks leave out much information about the operations of a carrier, but do provide sufficient data to establish four empirical relationships that define the weight and the volume required by the air wings of the SEC and the SECN as functions of the number of aircraft.

For the SEC:

$$W_A = 1089 + 122.1\ N_{A/C}$$

$$V_A = 27300 + 2700\ N_{A/C}$$

For the SECN, the equations become:

$$W_A = 1089 + 149.4\ N_{A/C}$$

$$V_A = 27300 + 2750\ N_{A/C}$$

Platform Requirements

In the last fifteen years of SES development, a series of relationships has evolved to estimate the weight of an SES platform. No similar relationships were available for volume prediction, but two SES point designs completed for the ANVCE study provided volume summaries that served as the basis for estimating equations. These point designs were also compared to the weight equations and modifications made to correspond to the weight breakdown results of these designs. The changes were made because these ANVCE designs reflected the same 1985 technology that would be available for the SEC.[4]

SEC combat suite weight of 329 metric tons is divided among SWBS groups as shown in Table VI. The suite was selected from the ANVCE SES-CV suite.[5] Reduction in

TABLE VI

SHIP COMBAT SUITE

GROUP 400	WEIGHT (mT)	GROUP 700 ITEMS	WEIGHT (mT)	ORDNANCE LOAD	WEIGHT (mT)
Aegis Radar & FCS	80	40-Tube Vertical Launcher	25	32 LARM*	60
				8 Harpoon*	14
2-D Long-Range Radar	5	6 Tomahawk Launchers	4	12 Tomahawks	46
Track-While-Scan FCS(2)	6	3 ASDM Launchers	15	72 ASDM	10
Electronic Warfare	3	ERAP Launcher	2	12 Rocket ERAPS	4
Cryptological ESM Sys.	9			6 Linear Arrays and Support	4
APS-116	2			48 Dropline Arrays	6
ASW Combat Electronics	9				
C^3	25				
TOTAL	139	TOTAL	46	TOTAL	144

*In armored cannisters.

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missile capacity was felt necessary to make the SES less a cruiser and more a sea base for aircraft which, in turn, would deliver the missiles.

The ANVCE margin of 15% was included and all ANVCE guidelines concerning engine performance and fuel consumption were observed. The structural weight relation was modified to reflect the latest increasing trends observed by DTNSRDC while monitoring the current effort to produce an SES by Rohr Marine. In addition, 100 metric tons are added to the structural weight for a superstructure consisting of an island and an overhanging flight deck. Finally, the fuel load for the ship is an approximation of the results of the DTNSRDC performance program results. This approximation was verified for the selected design case by comparison with that computer routine.

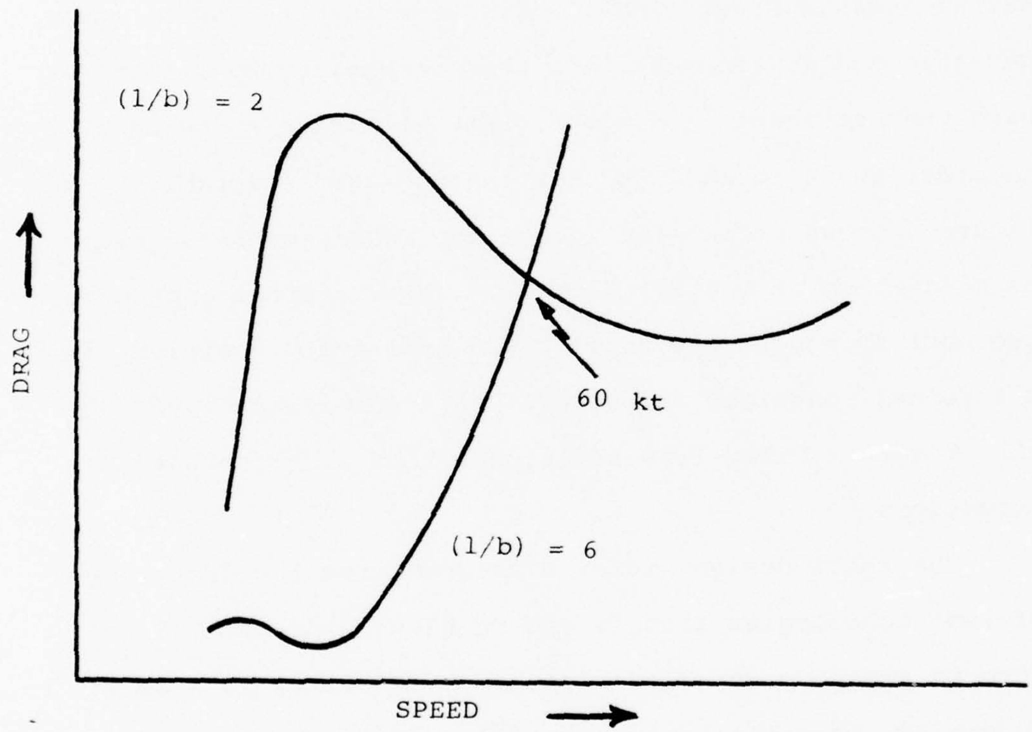
Critical Design Decisions

Before presenting the weight and volume relationships for the platform, three critical design decisions that influenced the platform requirements need to be reviewed. First, the full load design speed shown in ANVCE for sea state 3 (average wave height of .875 m) was set at 50 knots. The platform was required to carry sufficient fuel for a range of 6,000 nautical miles.[6] The selection of this design speed affected the installed power requirements and caused the higher cushion length-to-beam ratios of 5-7 to be investigated. The reason for this latter choice can be seen in Figure 3 where typical drag curves for two different

cushion length-to-beam ratios are presented.[7] The SES design with a higher length-to-beam ratio has less drag below 60 knots, greater economy in fuel and more operational flexibility at those speeds than an SES with a cushion length-to-beam ratio of 2 or 3.

FIGURE 3

SES DRAG FOR TWO CUSHION LENGTH-TO-BEAM RATIOS

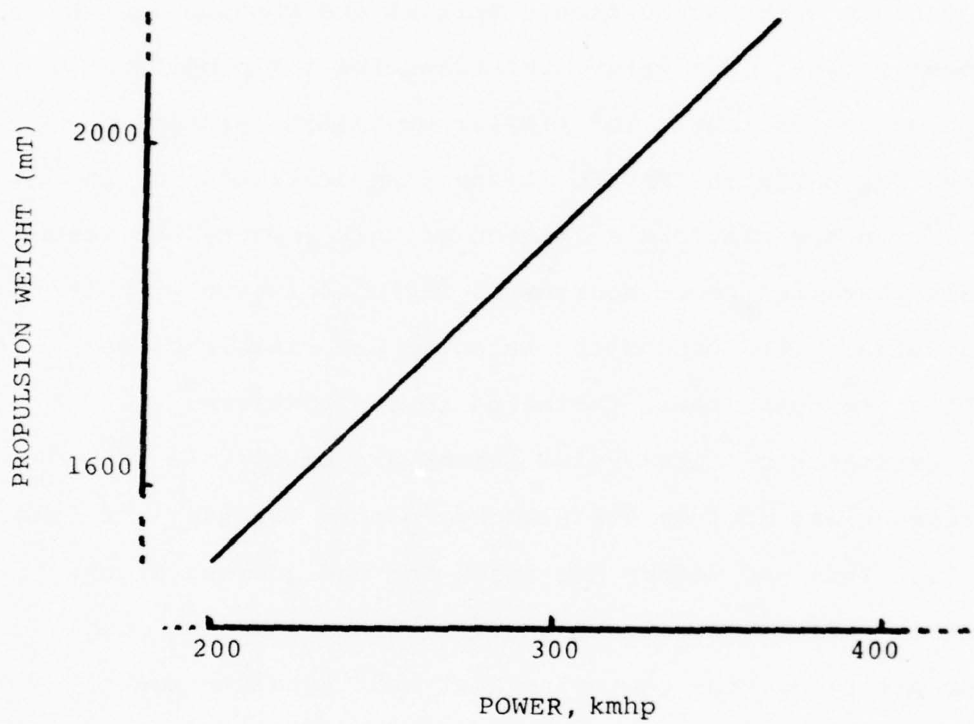


The second critical design decision resulted from the Congressional requirement that all major combatants be nuclear-powered. Consequently, a nuclear SEC, the SECN, was developed to examine an alternative design that satisfies Title VIII. However, the nuclear power plants currently installed in Navy ships have too high a weight-to-power ratio (32 mT/kmhp - 16 mT/kmhp) to be applicable to an SECN. It was, therefore, necessary to consider Light Weight Nuclear Power (LWNP)[8], discussed by the ANVCE study. Research and development into this technology by the Navy have been retarded.[9] However, LWNP will have to be used in order to build an SECN that can operate acceptably. Figure 4 shows propulsion weight for LWNP propulsion plants as a function of installed power. These systems each have two nuclear reactors with electric generation equipment in a shielded container and electrical transmission lines to all motors. Fifty-five additional tons were included for propulsors.

The third design decision stemmed from the development of two technologies that seemed to blend with the SES hull form to create a superior platform. The first is a semi-submerged super-cavitating propellor providing propellor efficiencies greater than 70°. This technology, when coupled with an electric drive power transmission system, such as that available from super-conducting cryogenic technology,

FIGURE 4

LIGHTWEIGHT NUCLEAR POWER PLANT
PROPULSION WEIGHT VS. POWER



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results in a propulsion system with an efficiency 20% higher than the water jet propulsion employed in current SES designs. Electric drive offers the capability to set propellor rpm to optimize efficiency for the many thrust and vehicle speed

combinations a ship encounters. The effect of variable speed should be similar to that of the variable pitch propellors of the SES-100B.

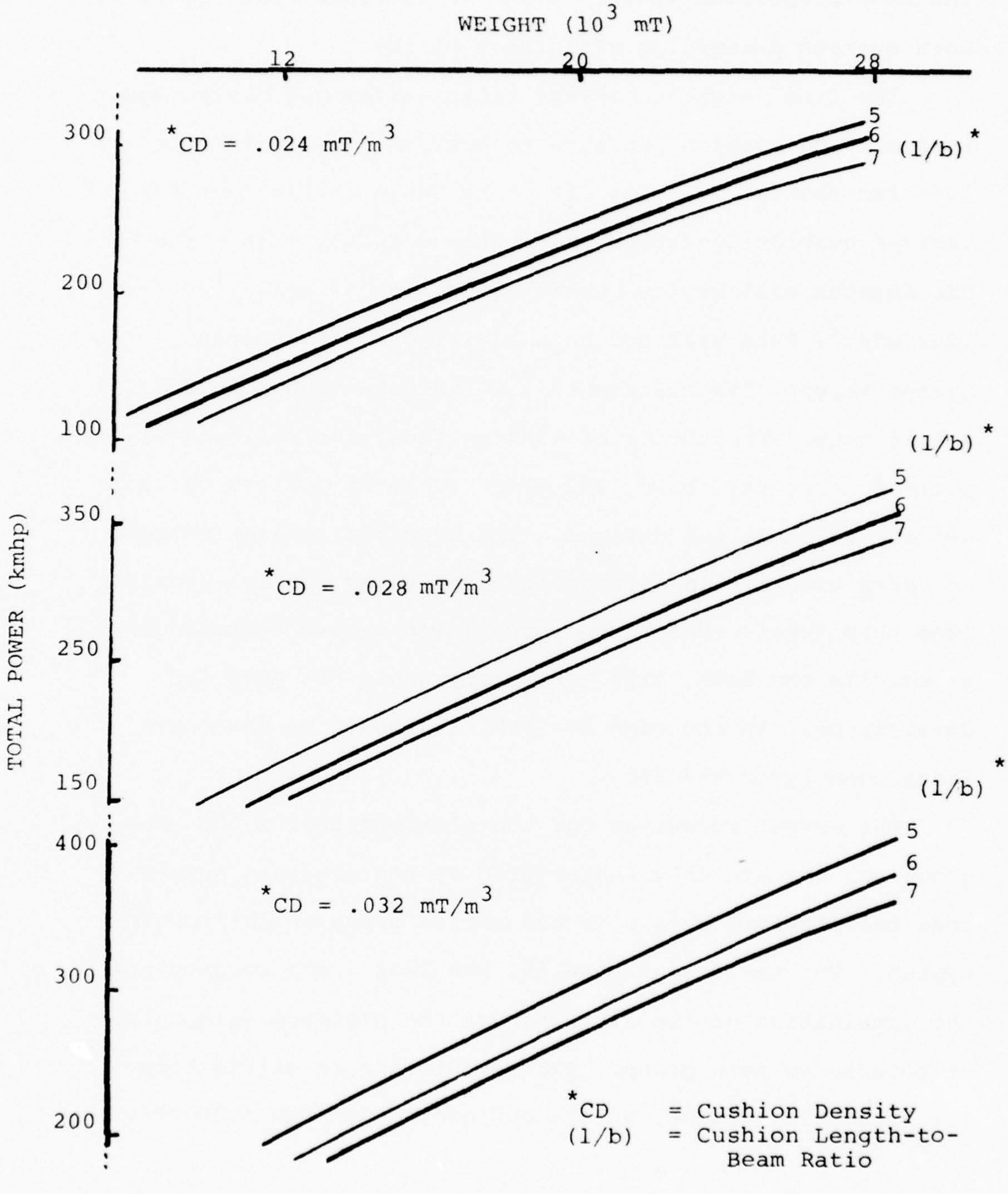
The total power requirements for an SES hull form with this type of propulsion system are given in Figure 5 for various weights, cushion densities and cushion length-to-beam ratios. The weight relationships for propulsion are based on the estimates for similar propulsion systems designed for ANVCE and NAVSEC in the form developed for the SES.[10] In the platform estimates of this report, the weight of all installed power sources is included in the propulsion weight. The propulsors selected are capable of absorbing the total power installed in the platform.

Estimates of lift system weight are based on a 70° efficiency and include the electric motors for the lift fans. The lift fans and motors are sized for one quarter of the power installed. Auxiliary power is drawn from the main power plant and for computing fuel and installed power requirements. The electric power transmission propulsion system permits the power distribution to these three requirements to be varied as required.

Propulsion system weight, W_{pp}, for the gas turbine SEC is a function of the number of gas turbines, N_E, and the maximum continuous power of each turbine in kmhp, (P) as shown below. This estimate assumes an electric drive train and semi-submerged, super-cavitating propellors.

FIGURE 5

TOTAL POWER REQUIRED VS. SHIP WEIGHT



$$W_{pp} = 1.04\ (.3P + 3.9P^{1/2} + .095P^{3/2})\ N_E.$$

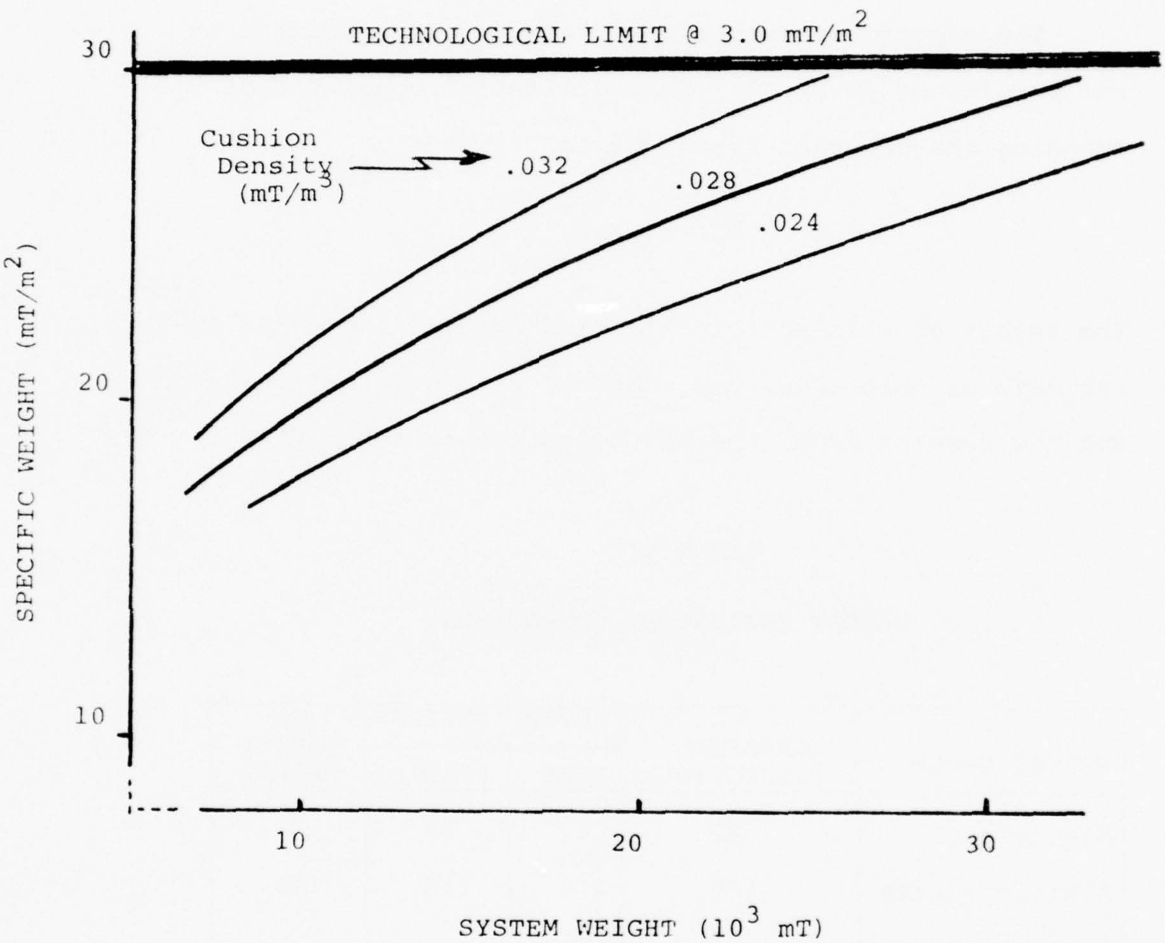
The LWNP propulsion system weight is obtained from Figure 4. Both systems assumed an efficiency of 68%.

The final high technology factor affecting design was to limit the cushion pressure to 3 mT/m^2, due to current lift fan technology. Its effect is shown in Figure 6 for various cushion densities and system weights. Since the SEC designs will employ cushion densities of only .024 - .032 mT/m^3, this will not be a limiting factor unless system weight ("displacement") is increased above 26,000 metric tons. The choice of cushion densities reflects experience that has shown .032 mT/m^3 to be an optimum cushion density for most SES designs. The need for greater volume to carry aircraft is obtained by decreasing cushion density from this level. Unlike the propulsion system technologies, especially the LWNP, lift technology would not pace SEC development. In the case of LWNP, it should be developed independently of the SEC.

The weight relations for the platform follow the SWBS grouping, but are only subscripted by the grouping number when the platform weight is the entire group weight for the system. For the design results, the SWBS group weights are the combination of the air wing and the platform weights attributable to each group. All weights are in metric tons. The structural weight, W_s, is defined by the equation below

FIGURE 6

EFFECT OF LIFT FAN TECHNOLOGY LIMIT



developed at DTNSRDC, except for the final term which adds 100 metric tons to account for SEC superstructure.

$$W_s = .1265\ (l/b)^{\frac{1}{4}}(CD)^{-\frac{1}{2}} \left\{ W^{-1/3} + .4135\ (l/b)^{-1/3} \right\} W + 100$$

where: (l/b) = cushion length-to-beam ratio

CD = cushion density

The electrical weight (W_E) relation was modified by the results of ANVCE.[11] The modification consisted of changing the constant from .025 to .02:

$$W_E = .02\ W.$$

The result of this modification and others, including the estimate of ship crew, are compared with original relations and the results from the ANVCE designs in Table VII.

TABLE VII

WEIGHT ESTIMATION COMPARISON

WEIGHT GROUP	ORIGINAL PREDICTIONS	ANVCE DESIGNS		SEC DESIGN METHOD
		ROHR	BELL	
Electric	89	67	43	71
Auxiliary Life	199	118	112	119
Outfitting & Furnishing	228	196	173	196
Ship's Crew	222	141	140	153

The command and surveillance weight, W_{400}, consists of combat suite electronic equipment and platform communication and control weights. The weight is held constant at 139 mT throughout.

The ship crew size, N_{CS}, is a function of the system weight, calculated by the formula $N_{CS} = .5W^{.7}$. This equation is included in the weight relations because the ship's crew size affects both auxiliary and outfitting weight estimates. The relation is a modification due to ANVCE results which indicated that the exponent should be changed from the previous .719 to .7 and the constant from .6 to .5.

The auxiliary weight, W_{aux} of an SES includes its lift system weight, W_{567}, and two other components: crew size and system weight. Both components were modified by the ANVCE results. The crew component constant was increased from .083 to .1, while the weight component constant was reduced to .015.

$$W_{567} = .367\ N_E P + .12\ b_c,\ \text{mT};\quad W_{aux} = W_{567} + 1\ N_{CS} + .015\ W^{1.08};$$

where b_c is the cushion beam in meters;

outfitting weight (W_{600}) is: $.15\ N_{CS} + ./035\ W^{1.08}$.

Armament weight (W_{700}) is a constant 46 mT, allowing for weapon launchers, but not for the canisters or the weapons themselves. The weapons and their canisters, along with deployable sensors, are included in the ship ordnance load.

Remotely-Piloted Vehicles (RPVs) and their support equipment are a secondary vehicle load. The RPVs are used to monitor deployed sensors and to provide over-the-horizon targeting data when the simplicity of the operation permits. The RPVs should save aircraft operational hours.

A platform margin of 15% of the above weights was included. Total platform weight is not only the sum of the above and the margin, but requires three additional weights, those of ship ordnance (W_{ord}), ship's crew (W_{SC}), including personal gear and provisions, and fuel (W_{FS}).

$$W_{ord} = 144 \text{ mT}$$

$$W_{SC} = .38\ N_{CS}$$

$$W_{FS} = \frac{(N_E)(P)(SFC)(Range)}{\text{Average Speed}} ,$$

where P is selected as about 50 kmph such that N_E is an integer. SFC is specific fuel consumption which, for gas turbines providing 50 Kmhp, should be .161 mT/hr/Kmph. The endurance range is 6,000 miles with an average velocity 1.15 times the design velocity.

Volume Relationships

Platform volume relationships are fewer, created for this effort by taking the volume summaries of ANVCE SES designs presented in Table VIII and dividing by the parameter

shown in each equation below.[12] These parameters were chosen since they were the ones most likely to influence each particular volume component. The equation for structural volume consists of two components. The first component is the volume required to contain the aluminum structural weight of the platform. The second component is the volume of the wall that makes up the outer sides of the ship, including armor.[13] All volumes are in cubic meters.

TABLE VIII

VOLUME SUMMARIES OF FAR TERM ANVCE SES DESIGNS

FUNCTION	ROHR	BELL
Propulsion & Lift	6483	5233
Auxiliary and Electrical	2859	1611
Personnel	3071	2278
Military Payload[a]	3672	2824
Other	3647	10593

[a]Does not include helicopter hangar.

Structural Volume:

$$V_{ST} = \frac{W_{ST}}{\rho_{AL}} + 2(l_o + b_o)\ h_o t_w$$

where: ρ_{AL} = the density of aluminum

l_o = overall length

b_o = overall beam

h_o = overall height, and

t_w = wall thickness of 1 meter.

Propulsion and Lift Volume:

$$V_{PL} = 32.3\ N_E P$$

(For the SECN, total power installed is substituted for $N_E P$).

Auxiliary and Electrical Volume:

$$V_{AE} = .782\ W$$

Personnel Volume:

$$V_P = 21.8\ N_{CS}$$

Military Payload Volume (including 20% future growth):

$$V_{mp} = 15(W_{400} + W_{700} + W_{ord})$$

Other (Miscellaneous) Volume:

$$V_o = W(mT)$$

Ship fuel volume, V_{FS}, is 105% of the ship fuel weight divided by the density of JP-5. The extra 5% is for overloading fuel.

$$V_{FS} = 1.3\ W_{FS}.$$

For the SECN, fuel weight and volume requirements are zeroed.

The above relationships that comprise the platform requirements cannot be reduced to anything as simple as the similar relations for the air wing. Yet, these equations represent the weight and the volume needs of the platform and are a function of three parameters, system weight, cushion density, and cushion length-to-beam ratio. These parameters also define the capacity of the entire system and its dimensions.

System Capacities and Dimensions

The capacities and dimensions of the SEC are functions of its weight, cushion density, and cushion length-to-beam ratio. The critical dimensions are the heights, lengths, and beams of the cushion and the overall ship and of the specific weight (w). This final parameter is slightly higher than the cushion pressure which technology limits to 3 mT/m^2. Cushion area (A_C) is not a necessary parameter but is included to simplify the rest of the equations. Hereafter, $CD = w/\sqrt{A_C}$,

$$A_C = (W/CD)^{2/3} \text{ and: } w = W/A_C .$$

Noting $A_C = l_c b_c$ by definition, then the cushion length, l_c, and beam, b_c, are calculated using the length-to-beam ratio ($R_{l/b}$):

$$l_c = (A_C\ (l/b))^{\frac{1}{2}}$$

$$b_c = A_C/l_c\ .$$

The cushion height (h_c) is assumed to be 8 meters, 2 meters higher than normally used in SES designs.[14] It affects the seakeeping of the SEC, although the gain in seakeeping for this increase is not quantified. Cushion height also affects the overall length (l_o), according to the rule-of-thumb design relationship:

$$l_o = 2.5^* h_c + l_c$$

(*This could range from 2.25 to 2.5).

The overall beam (b_o) is also a function of a design rule based on experience:

$$b_o = 1.2^* b_c$$

(*This could range from 1.2 to 1.3).

Beyond the limits shown, the model and manned test vehicle data base are lacking. A similar lack of data discouraged the investigation of cushion length-to-beam ratios above seven.

The final dimension derived is the overall height, a function of the enclosed volume. This volume is obtained by dividing the structural weight of the ship by a structural density, ρ_{ST} by rewriting the definition of structural density:

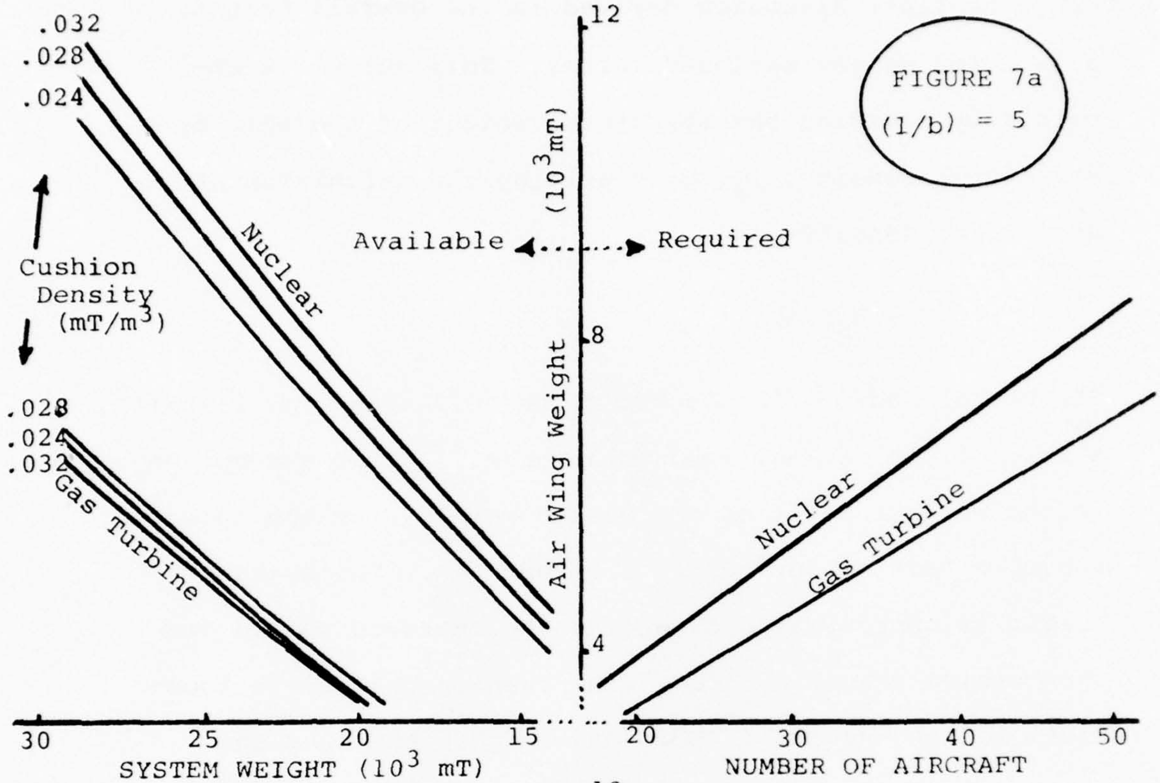
$$V = W_{ST}/\rho_{ST}.$$

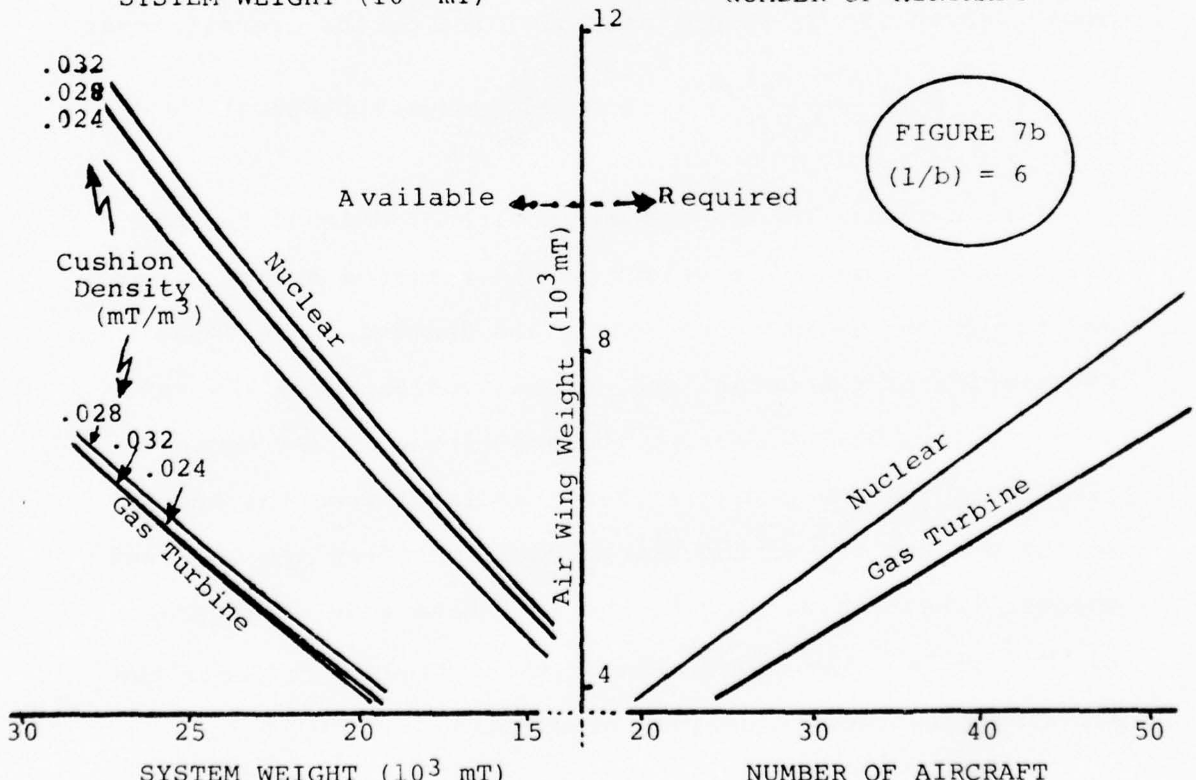
Structural density is assumed to be .032 mT/m^3, or 2 lb/ft^3, a lower limit for advanced hull types.[15] This assumption is the weakest point of the design method, but was selected due to a lack of any better alternatives. The overall height is approximated by adding the enclosed volume and the cushion channel volume. (The cushion channel is identical to the cushion in beam and height, but runs the whole length of the ship), then dividing by the overall area:

$$h_o = \frac{V + h_c l_o b_c}{l_o b_o} \quad \text{(excludes superstructure).}$$

The capacity of the system is already defined for both weight and volume. The weight is the selected system weight and the volume is the enclosed volume derived above. The calculation of the weight and volume available for the air wing consists of subtracting the sum of the weight equations (including the ANVCE margin where required) from the system weight and the sum of the volume equations from the enclosed volume. The results provide the left-hand side of Figures 7a through 7e. The right side of these figures reflects the air wing requirements derived previously.

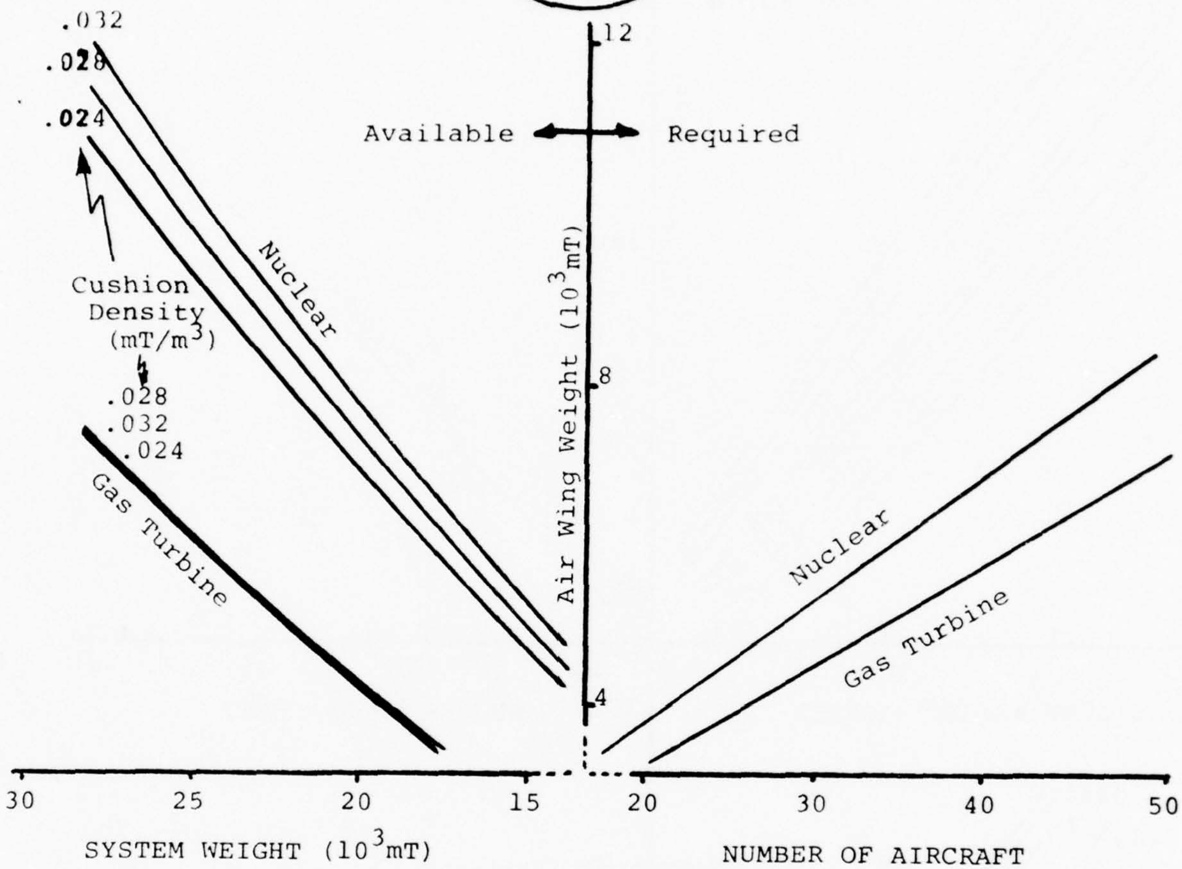
WEIGHT DESIGN CURVES





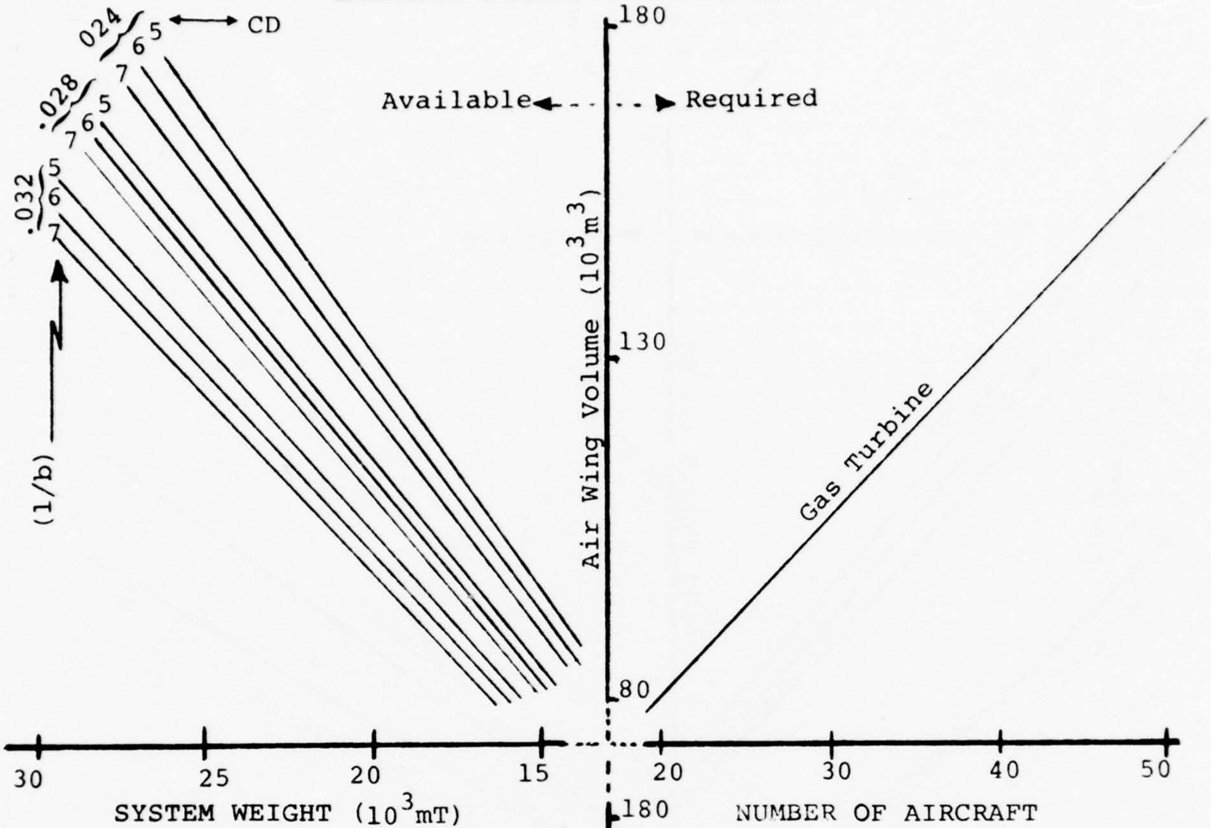
WEIGHT DESIGN CURVES

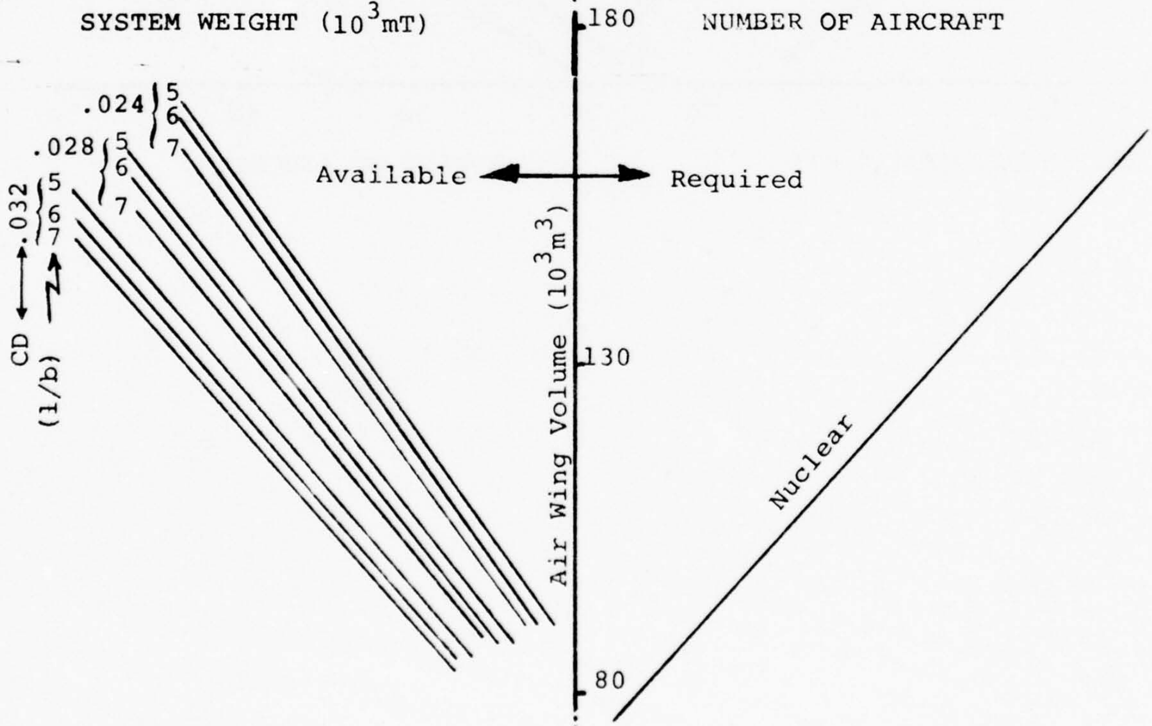
FIGURE 7c
(1/b) = 7



FIGURES 7d and 7e

VOLUME DESIGN CURVES





CHAPTER III

COST RATIONALE

The design feasibility of an SEC is the central issue of this report. Rather than developing a unique model to estimate costs of these designs, the ANVCE model was employed. Additional available information concerning potential costs was rather fragmented, but will be provided here as supplementary data to support the feasibility of the SEC and SECN concepts.

The factors that comprise any carrier's life cycle cost are aircraft procurement expenditures, total platform cost, and operating expenses, including fuel and personnel. The life cycle cost of sea-based aviation is dominated by the cost of the aircraft.[1] For the 1979 objective level of 13 CV/CVN, aircraft cost represents nearly 2/3 of the total (even though only 12 wings are funded), and underway replenishment group cost is about 10%. The life cycle cost of the 13 carriers required to carry the air wings (43% investment and 57% operating) is only half of the cost of their aircraft. Assuming that the aircraft carried by the SEC or the SECN will be almost identical in number and design to those on a CV or CVN, then the expenditures for the equipment would be equal for both. Consequently, it is considered unnecessary to discuss that facet of the life cycle cost. Emphasis will be placed on the two factors affecting platform life cycle cost.

The first of these factors is procurement cost, or investment. The high cost of engineering involved in building the lead ship of the SEC concept will make it the most expensive to produce. The first follow-ship should cost approximately one billion dollars less than the lead ship and the experience gained in production should reduce the cost of succeeding ships. Such cost decreases would occur only if no major changes in the ship were necessary. Figure 8 displays this decreasing cost in terms of cost per platform when the lead ship is included (upper curve) and when it is not (lower curve). The combat suite and air wing cost are not part of the estimate. Figure 9 presents the same data for the SECN. These graphs also show comparative investment figures for a CV and CVN. The LWNP plant was the only item of GFE whose cost was included as investment.

The second factor that determines ship life cycle cost is the expense of operations and maintenance. This is difficult to estimate for futuristic ship designs. However, if only fuel and personnel cost are considered, then an estimate of the cost can be made. Since air wing composition on conventional and on surface effect carriers would be identical, differences in their fuel cost can be neglected.

To keep this paper unclassified and thus gain a wider audience, the specifics of fuel consumption comparisons between a CV and the SEC will not be detailed herein. At

FIGURE 8

SEC PROCUREMENT COST

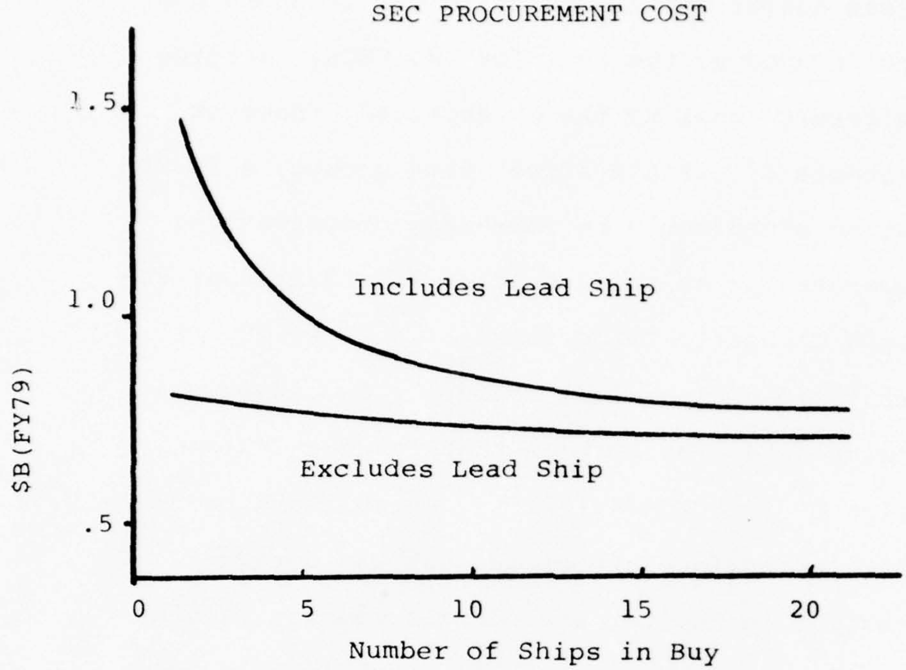
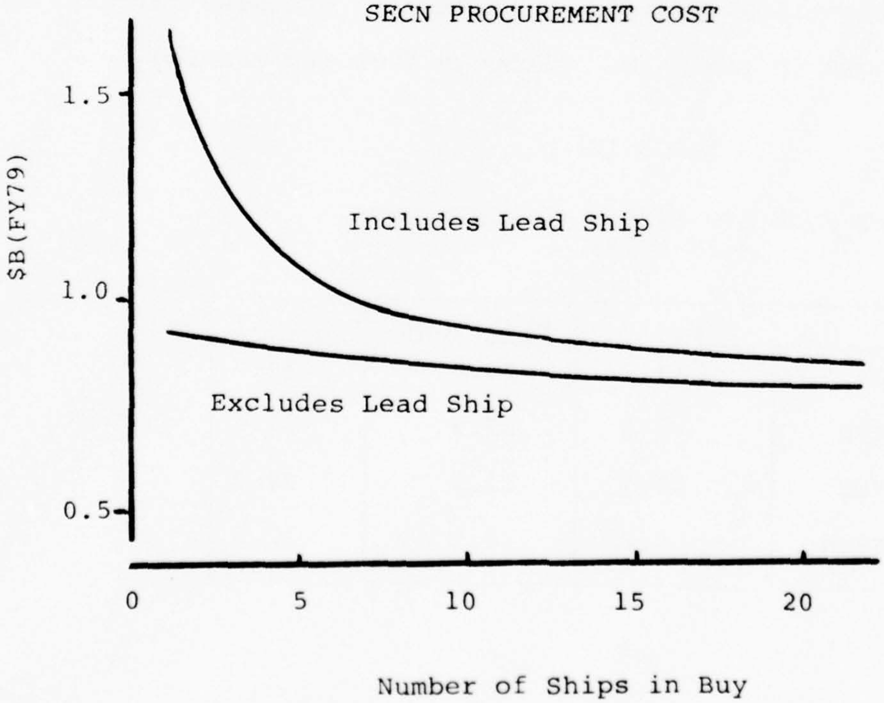


FIGURE 9

SECN PROCUREMENT COST



the 20 kt speeds normal for an operating CV, it would cost about 25% more to procure the fuel for two SECs, carrying a number of aircraft equal to the CV deckload. However, given the existence of surface effect task groups, a 20 kt average operating speed would be extremely conservative. If the SECs operated at an average of 40 kt, their fuel requirements would be nearly twice those of a 20 kt CV. It was assumed that the nuclear fuel to supply two LWNP would cost nearly twice (194%) as much as that for one CVN.

Manning for CV and CVN designs is established by practice. That for surface effect designs was derived using the equations in Chapter II. Ship's company manning for the SES designs was estimated to be approximately one half the officers and one sixth the enlisted personnel required for conventional designs. The results of these calculations are shown in Table IX. Although fuel and manning

TABLE IX

ANNUAL FUEL AND SHIP'S COMPANY COSTS
($M FY79)

QTY		Fuel	Personnel	Total
1	CV	14.2	25.7	39.9
1	CVN	3.5	27.9	31.4
2	SEC	27.1	12.1	39.2
2	SECN	6.8	10.9	17.7

costs do not totally dictate operational and support costs, these factors are the most dominant in computing them. As such, the results indicate that the operation and support costs of the SEC and SECN would not be appreciatively more than for a CV or CVN.

After considering these investment, operation and support and aircraft expenditures, it seems reasonable to make the overall conclusion that replacing a single CV or CVN with two SECs or SECNs would not appreciably alter life cycle cost estimates. It must be understood, however, that the conclusions must be tempered by the uncertainties that always are part of developing any new concept, and by the fact that research and development expenses are not included.

CHAPTER IV

RESULTING SEC DESIGN

These findings consist of two sections: one composed of general data where characteristics and cost were determined and compared for six designs, three each for the SEC and SECN, and the second dealing with the specific design chosen for tactical examination in the final part of the study.

General

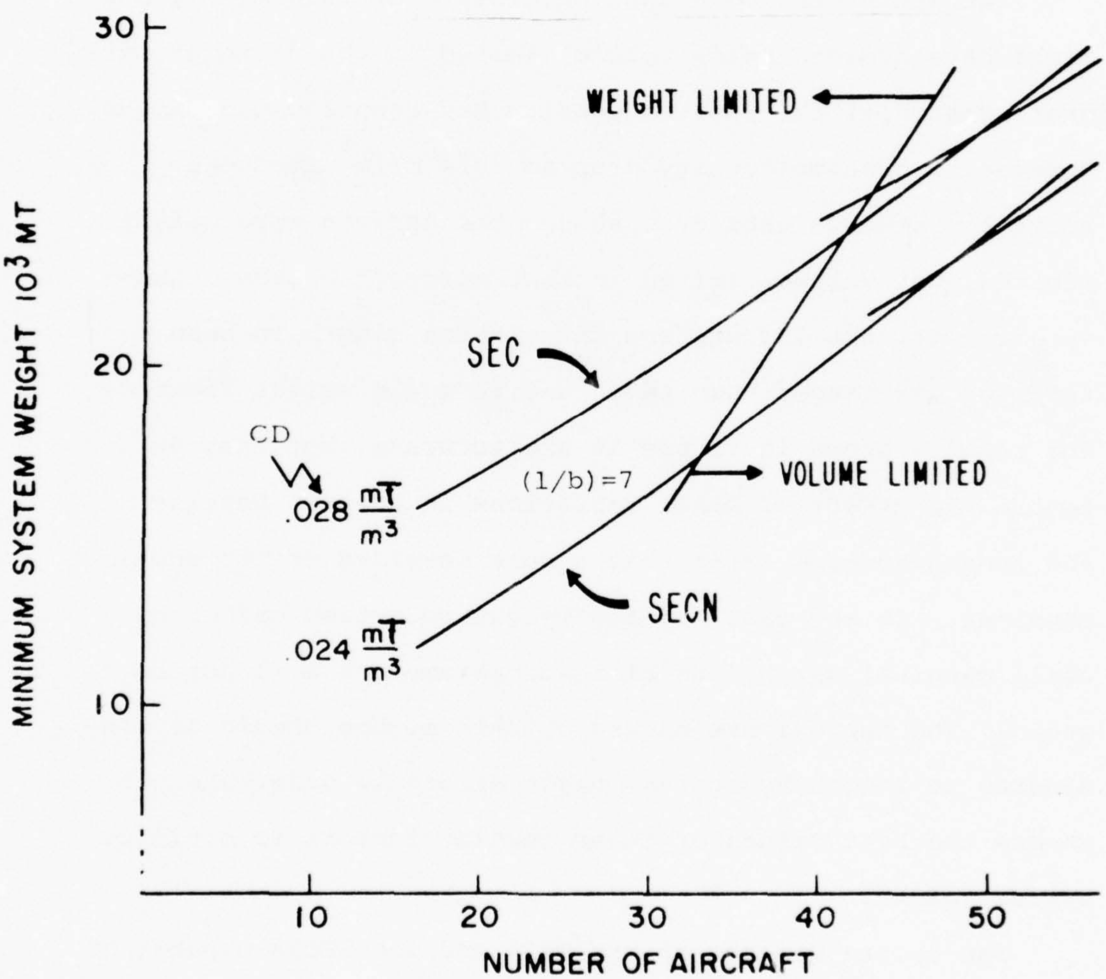
The final design relationships in Chapter II were examined to determine the minimum weight SEC and SECN systems. This analysis was undertaken because of the conviction that the lowest weight system to carry a given number of aircraft would be the cheapest.

Figure 10 shows the results of the analysis. Both the SEC and SECN are weight limited for small air wing sizes. The SECN became volume limited at 33 aircraft and always required a cushion density of .024 mT/m^3 for sufficient payload volume. For air wings larger than 33 aircraft, the SECN became heavier, not from weight, but to provide required additional volume, even when cushion length-to-beam ratio was left equal to six. Lower cushion length-to-beam ratios provide more volume, but at W = 23,000 mT the

increased volume was not sufficient to prevent volume requirements from controlling the design parameters. If volume had not been considered, the SECN would have preferred higher cushion densities to reduce its system weight.

FIGURE 10

MINIMUM SYSTEM WEIGHT AS A FUNCTION OF AIR WING SIZE



The SECN is significantly lighter than the SEC throughout the data shown in Figure 10, but the difference diminishes as the air wing size increases. This trend results from the diminishing value of LWNP with system size. The advantage of LWNP over gas turbine designs at a fixed endurance of 6,000 nm is clear for SES hull-type ships below a displacement of 25,000 mT.

The SEC preferred a cushion density of .028 mT/m^3, but might have avoided being volume limited in the 43 to 48 aircraft region if the cushion density had been lowered slightly. However, a cushion density drop to .024 mT/m^3 produced heavier system weights even though the designs were weight limited, not volume limited in that aircraft region. Above 49 aircraft, the SEC prefers the cushion length-to-beam ratio of six rather than seven and is again weight limited. The results shown in Figure 10 are accurate, but they do ignore the effect of small variations in cushion density and length-to-beam ratio that a more detailed effort should consider. In any case, system weight reduction gained by small marginal variations of these parameters will not be great. The approximate nature of this method should be considered at length before any major effort is undertaken to choose the best values of these cushion factors to optimize system weight.

The system weights of the SECs and the SECNs capable of carrying 30, 40, and 50 aircraft were determined from

Figure 10. In Table X, the costs for lead ship and follow ship designs for all six cases are estimated. Follow ship

TABLE X

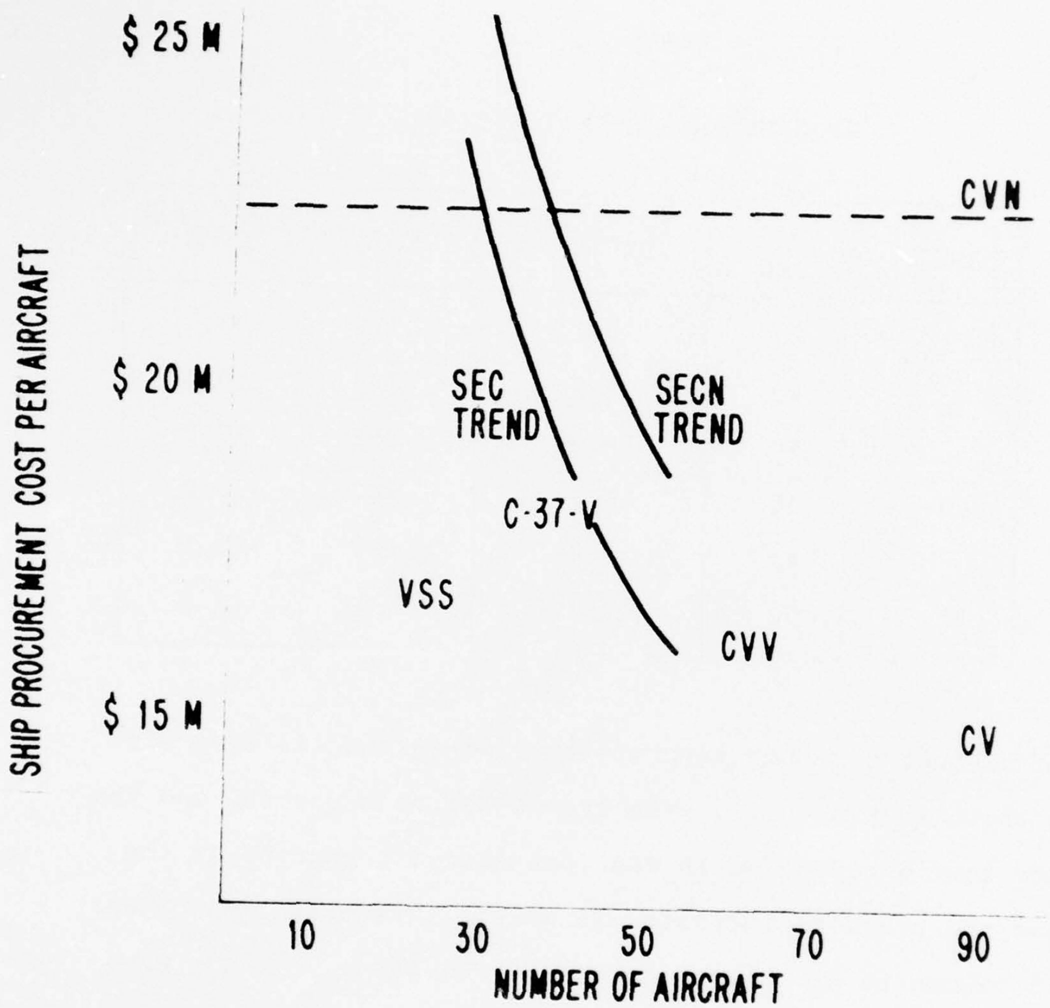
PROCUREMENT COSTS (FY79 $M)

VEHICLE	$N_{A/C}$	TOTAL LEAD-SHIP COST	COST OF FOLLOW-SHIP TOTAL	PER A/C
SEC	30	1661	712	23.2
	40	1851	788	19.7
	50	2025	858	17.2
SECN	30	1567	787	26.2
	40	1784	897	22.4
	50	1951	980	19.6

procurement cost per aircraft carried versus air wing size is shown in Figure 11. The trends for both the SEC and the SECN show a reduction in cost per aircraft carried as the wing and platform increase in size. This trend is logical and common to any series of carrier designs. The SEC becomes cheaper than a CVN at wing sizes greater than 32 aircraft. The SECN must carry 38 aircraft to satisfy this criterion. Both concepts are capable of being developed in such a way as to permit two of either type, each carrying half a CVN air wing of 90 V/STOL, to be procured for the price of the CVN.

FIGURE 11

DESIGN COST TRENDS



Specific Designs

The SEC and the SECN designs carrying 45 aircraft are nearly identical. Their dimensions, weight, and volume requirements are given in Table XI. The flight deck, hangar decks, and machinery deck for the SEC are as depicted in Figure 12. The SECN design has the same layout except the ship is a meter longer and the LWNP and its generators are substituted for the gas turbines and their generators in the SEC. These changes are shown in Figure 13. Machinery and crew sections are based on the ANVCE designs. The ANVCE SES-CV design showed similar beam, deck heights, and aircraft operational requirements as the designs of this report. Its propulsion system was also similar but employed a different lift fan design and lacked the drawings required for the machinery layouts. The propulsion and lift system of the Rohr SES combatant was similar in power and lift requirements. The Rohr report also had an electric drive, semi-submerged, supercavitating propellors and provided data that made possible the details shown in Figures 12 and 13.

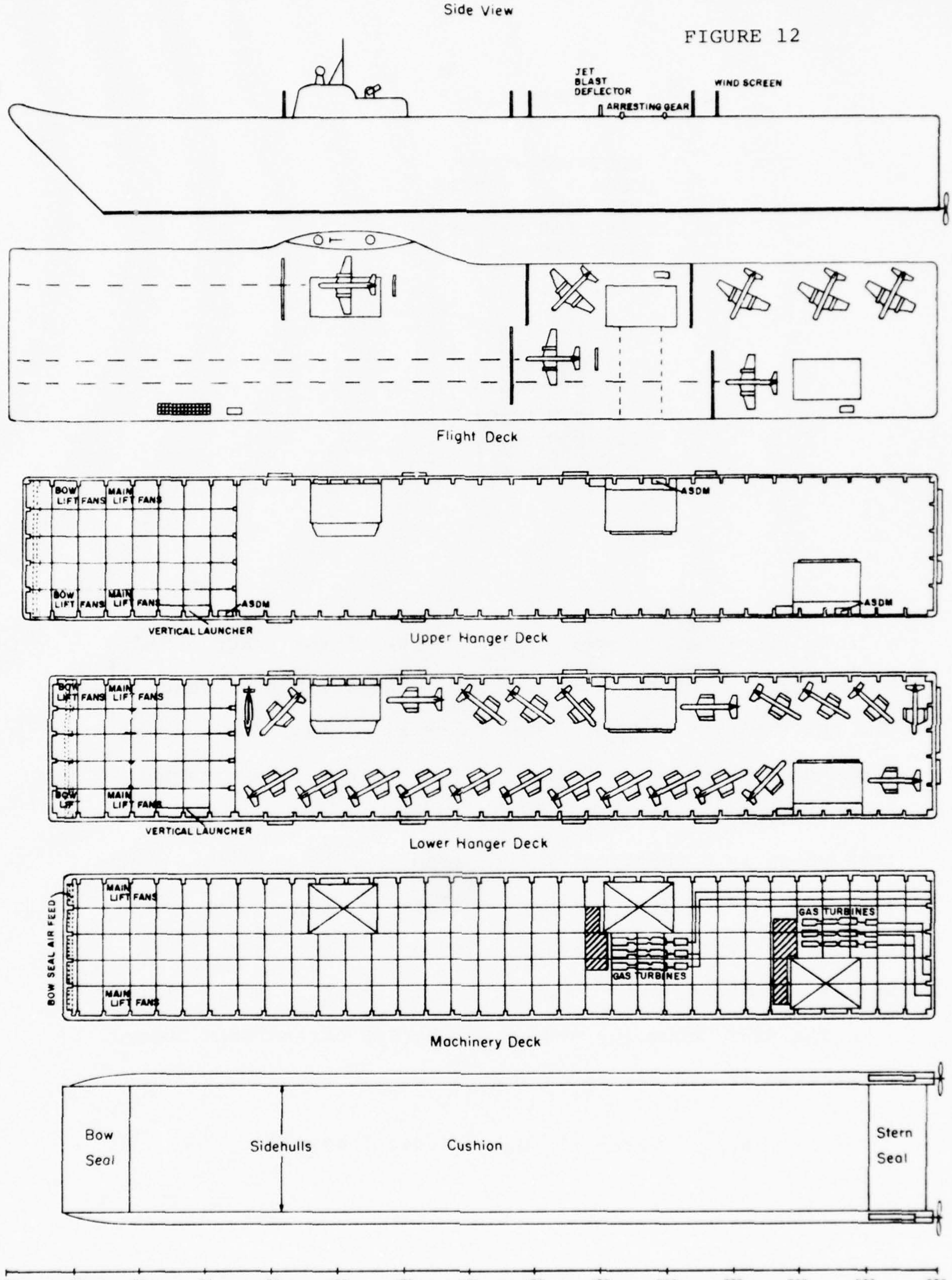
Table XI summarizes the combined weights of the platform and the air wing for both designs. Extra weight resulting from slight overestimation of the system weight has been assigned to fuel for aircraft. Although a complete review of each weight category is beyond the depth of this

TABLE XI

CHARACTERISTICS OF DESIGNS

CHARACTERISTICS	SEC	SECN
Dimensions:		
Length (m)	278	279
Beam (m)	44	44
Height (m)	26	26
Cushion Area (m^2)	9546	9583
Length (m)	258	259
Beam (m)	37	37
Height (m)	8	8
Crew	1741	1682
Powering	6 (54 Kmhp) Gas Turbines	2 (130 Kmhp) LWNP reactors
Weights (mT):		
Group 100	8390	7771
200	515	1738
300	520	450
400	139	139
500	1812	1655
600	1628	1428
700	46	46
Margin	1958	1984
Lightship	15008	15211
Loads:		
Crew Related	662	639
Secondary Vehicles	1065	1065
Ordnance	1467	1904
Fuel	7798	3681
TOTAL	26000	22500
Volume (m^3)		
Structure	18000	18100
Propulsion & lift	10400	8300
Auxiliaries & Electric	20300	17600
Crew	38000	36700
Military Payload	6600	7100
Fuel	10300	5000
Hangar Decks	116300	116300
Other	29800	30900
TOTAL	249700	240000

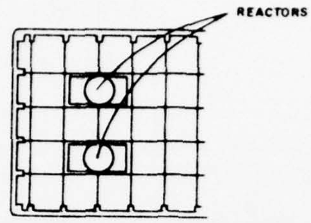
FIGURE 12



Side View
JET
BLAST
DEFLECTOR
ARRESTING GEAR
WIND SCREEN
Flight Deck
BOW LIFT FANS
MAIN LIFT FANS
ASDM
VERTICAL LAUNCHER
Upper Hanger Deck
BOW LIFT FANS
MAIN LIFT FANS
VERTICAL LAUNCHER
Lower Hanger Deck
BOW SEAL AIR FEED
MAIN LIFT FANS
GAS TURBINES
Machinery Deck
Bow Seal
Sidehulls
Cushion
Stern Seal
0 20 40 60 80 100 120 140 160 180 200 220 240 260 280

FIGURE 13

MODIFICATION TO
FORWARD 40 METERS
OF THE MACHINERY DECK
OF SEC FOR THE SECN
(SEE FIGURE 12)



effort, problems discovered in a review of the ANVCE SES/CV make a review of at least the Group 100 weights prudent. The ANVCE SES/CV structure was taken as a model for the designs of this report. Analysis of Group 100 weight estimated by the ANVCE review group breaks it into three categories: that which is a function of deck area, weight that is a function of platform length, and miscellaneous weight that would be constant for similar ships. The division of structural weight components into these groups is shown in Table XII.

The SWBS Group 100 weight of the SEC or the SECN, based on Figures 12 and 13, is estimated as:

$$W_{100} = .3345\ (l_o \cdot b_o) + 7.044\ l_o + 376.$$

TABLE XII

REVISED WEIGHT ESTIMATE GROUPS

DECK AREA	OVERALL LENGTH	MISCELLANEOUS
Flight Deck	Bulkheads	Deckhouse & Mast
Hangar Deck	Side Hulls	Special Structure
Gallery Deck	Foundations	A.C. Handling
Machinery Deck	Bolts, Welding	Fire Door, Stanchions, Trunks, Platforms

Table XIII compares the results of this equation with the ANVCE design method's estimate of Group 100 weight, and shows that the design method's estimate is higher. This result should promote confidence in all the weight estimation formulas of the design method.

TABLE XIII

COMPARISON OF SWBS GROUP 100 WEIGHTS (mT)

CONVENTIONAL POWER		NUCLEAR POWER	
ANVCE	SEC	ANVCE	SECN
8390	6426	7771	6448

Volume was more difficult to determine and is more likely to be in error. Based on an overall height of 28 m, not including the island, a distribution of deck heights is provided in Figure 14. The distribution includes the design assumptions of hangar deck heights of 6 m for the upper deck and 7 m for the lower deck and a cushion height of 8 m. The thickness of the decks used here are greater than these used by ANVCE for the SES-CV and are given in Table XIV. The resulting machinery deck height is 2 m.

TABLE XIV

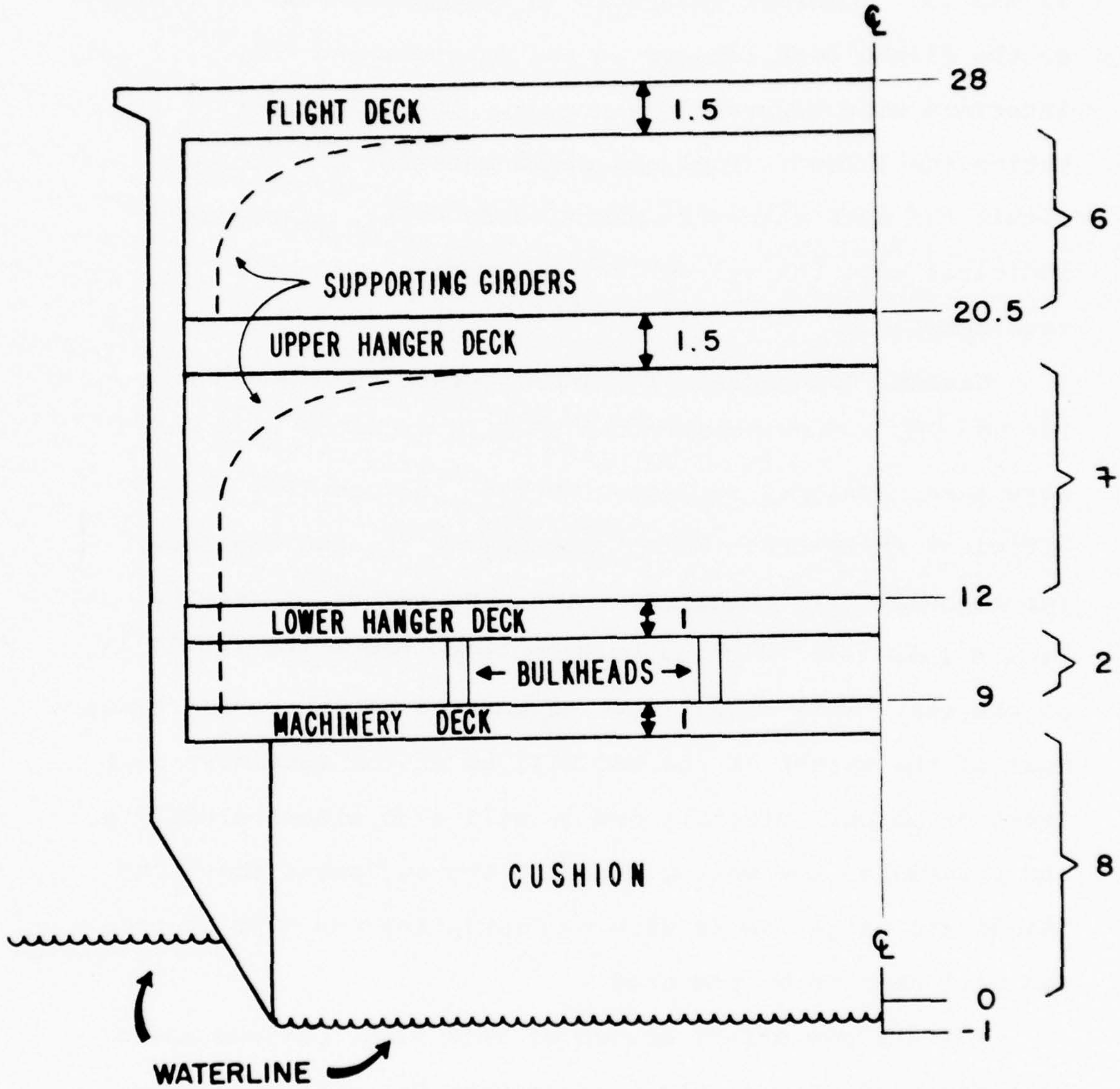
DECK THICKNESS (m)

DECK	THICKNESS	HEIGHT FROM KEEL
Flight Deck	1.5	28.0
Upper Hangar Deck	1.5	20.5
Lower Hangar Deck	1.0	12.0
Machinery Deck	1.0	9.0
Upper Gallery Deck	.4	23.9
Lower Gallery Deck	.4	16.2

Forward of the area required to stow aircraft, the gallery decks divide each hangar deck into two decks for crew spaces. Deck height in all these spaces is 2.8 m, except for the lowest level which is 3.8 m. The volume requirements

FIGURE 14

DECK HEIGHTS AND THICKNESS
(DIMENSIONS IN METERS)



of the designs given in Table XI are parceled out by decks in Table XV. Note that the vertical launchers of the ship are included in the hangar deck volume, as shown in Figure 12 and 13. Tomahawk launchers in cannisters must be placed on the flight deck forward of the island where they will not interfere with aircraft operations. The ERAP launcher is behind the island. Fuel and other material are stored within the deck structure where voids exist. Table XV indicates that the system can accommodate all the volume requirements.

Careful management of volume appears to be necessary for the SEC and especially the SECN in order to give the structural designer sufficient volume to formulate an efficient framework. Weight management is also necessary for the stability requirement that the center of gravity remain less than half the cushion beam, above the level of the sea. This requirement appears to be no problem since most of the weight of the SEC will be at the machinery deck level or below. Sidehull design will also affect stability, and procedures for moving aircraft and equipment about the flight and hangar decks without disrupting the trim of the SEC will need to be prepared.

For surface effect design of this size, maximum speed will diminish only slightly (less than 5%) with increasing sea state. The reduction may be more severe if ride quality

TABLE XV

VOLUME DISTRIBUTION (m^3)

COMPONENTS	UPPER GALLERY	UPPER HANGAR	LOWER GALLERY	LOWER HANGAR	MACHINERY	SIDEHULLS	HULL STRUCTURE*
<u>SEC</u>							
Fuel							10300
Structure							20100
Powering	1210	1210	1210	1640	3200	1630	300
Aubiliaries		2200		1890	8410	3100	4700
Personnel	5600	7500	4700	8500	6000	3000	2700
Combat Suite	200	610	200	590	5000		
Air Wing		46710		54530	1510		3030
Other	520	1610	480	2750	2450		29570
TOTAL	7530	59840	6590	69900	26570	9000	70700
<u>SECN</u>							
Fuel							5000
Structure							19880
Powering	1110	1110	1200	2010	910	1630	330
Auxiliaries		2640		2890	6230	1260	5200
Personnel	5800	7700	4800	8400	5300	2000	2700
Combat Suite	200	610	200	590	5500		
Air Wing		46710		54530	1510		3030
Other	540	1090	510	1640	820	610	34310
TOTAL	7650	59960	6710	70060	20100	5500	70450

*Structure refers to volume filled with structural material. Hull structure means total volume of the ship's structural frames including voids usable for storage.

rather than powering is the limiting factor. However, the installed lift system is capable of reducing motions in the manner included in the current SES design. Maximum SECN speed will increase with a decrease in expendables. This effect is not shown but will be similar to that of the SEC shown in Figure 15. The SEC performance changes with sea state are also displayed by this figure. For SES design, maximum speed is determined with 50% of fuel aboard.

Perhaps the most intriguing aspect of SEC performance is the comparison of the fuel consumption rate of the two SECs with a CV, as shown in Figure 16. Both the CV and the pair of SECs could carry similar V/STOL air wings. The single CV would consume fuel at a slower rate only for speeds below 28 knots. Above 28 knots, the CV would require increasingly greater amounts of fuel than the SECs. Or, turning this chart around, CV fuel consumption at about maximum speed would permit two SECs to operate above 50 kt. Figure 17 displays the range of the SEC as a function of speed and sea state.

Table XVI compares the fuel, ordnance, and cost per aircraft of other carrier designs with the SEC and the SECN.[3] Its purpose is to show that the surface effect designs compare favorably (in cost to support an air wing) with the other carriers presently under consideration for the future Navy. The additional speed of these concepts is, however, a distinct advantage which no other hull form can provide.

FIGURE 15

MAXIMUM SPEED AS A FUNCTION OF EXPENDED LOADS AND SEA STATE FOR THE SEC

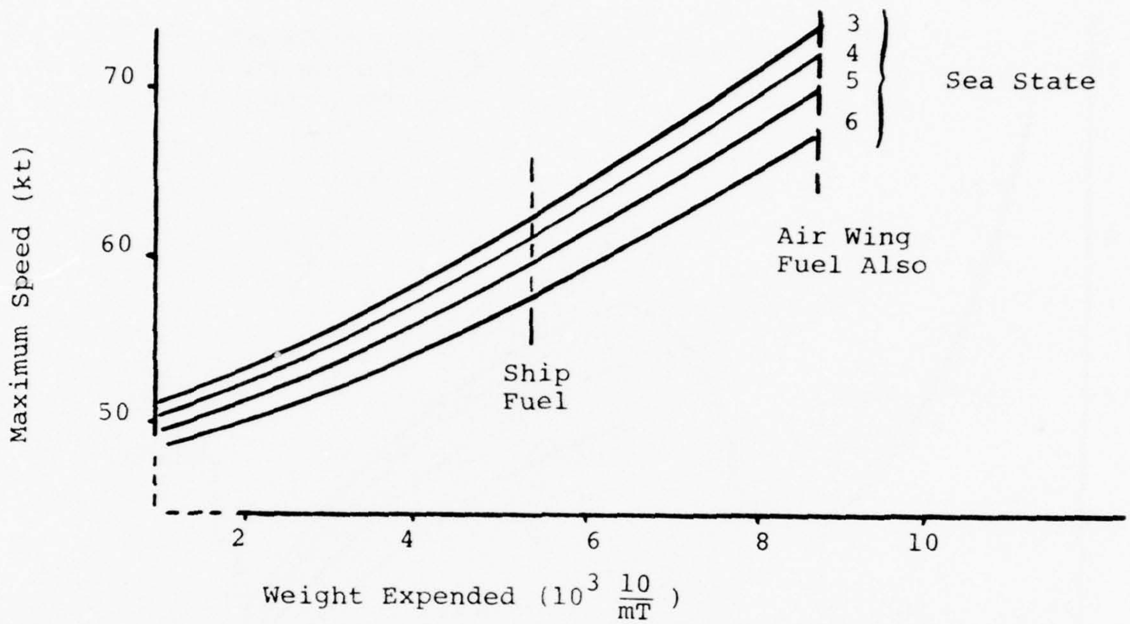


FIGURE 16

COMPARISON OF AN SEC AND CV FUEL CONSUMPTION

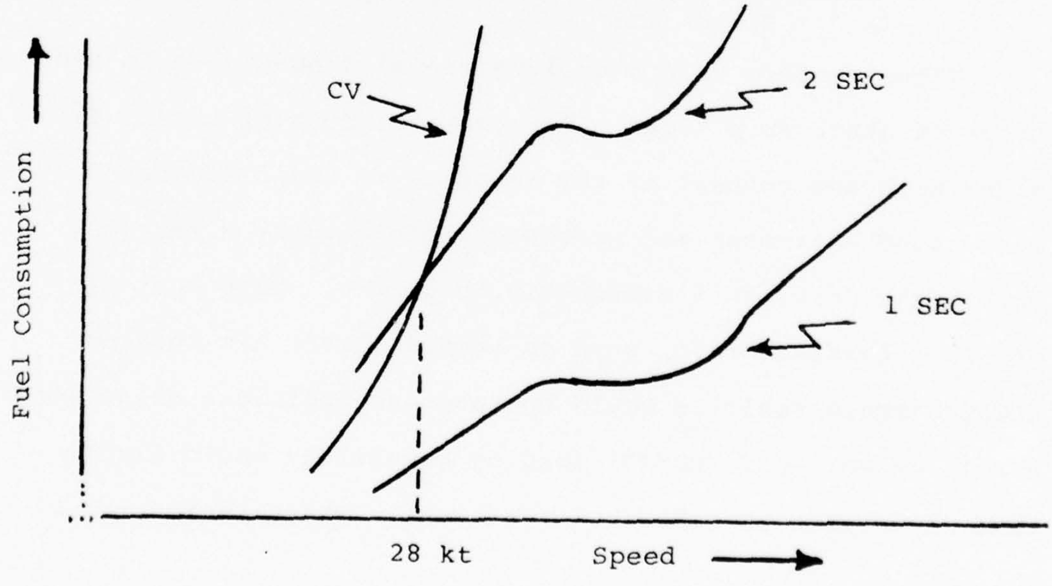
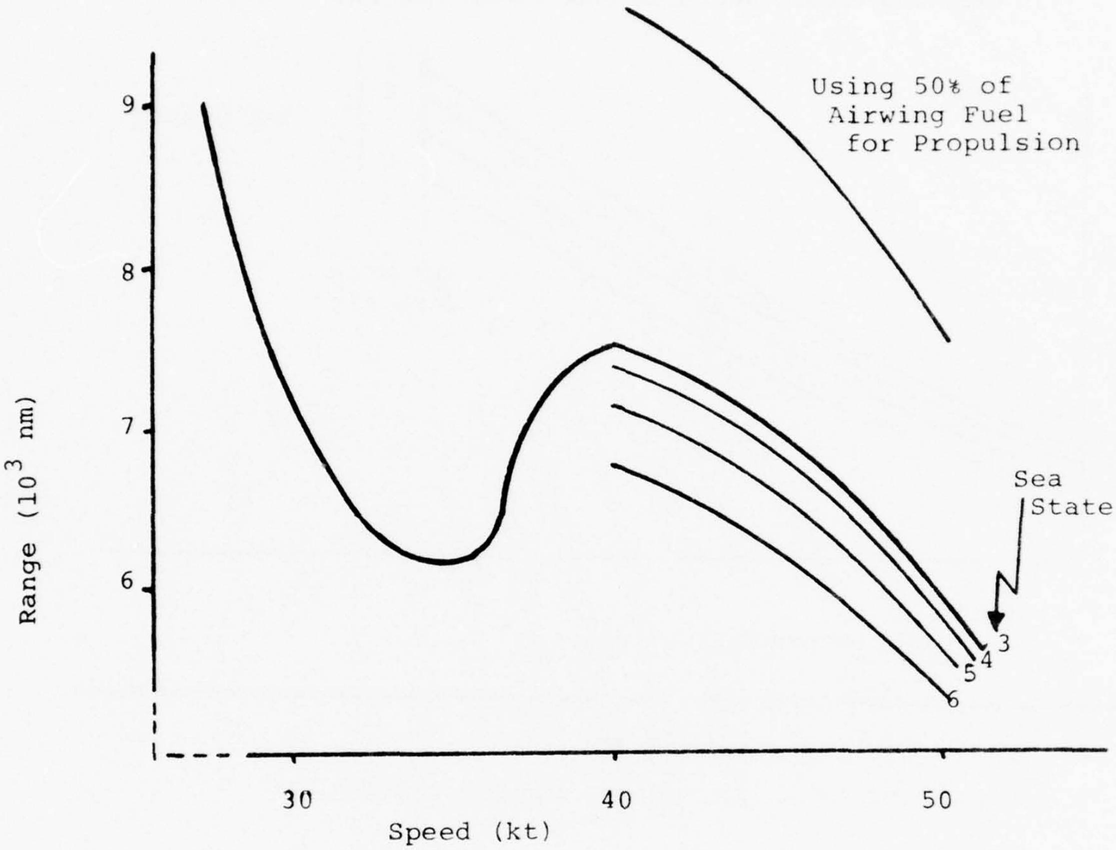


FIGURE 17

RANGE OF THE SEC AS A FUNCTION OF SPEED



These surface effect designs are also adaptable to the roles of other ship types. For example, both of these designs with the removal of the majority of their aircraft, associated equipment and personnel, could carry a Marine Amphibious Unit, as discussed in Chapter V. With suitable dry well landing craft, such as Landing Craft Air Cushion (LCAC), these vehicles could operate as amphibious ships and a Roll-On/Roll-Off (RO/RO) loading capability would facilitate conversion to other roles as well. These varied roles

TABLE XVI

COMPARISON OF FUEL, ORDNANCE AND COST

CARRIER	SIZE OF AIR WING	PER AIRCRAFT		
		FUEL (mT)	ORDNANCE (mT)	COST (mT)
CVN	90	125.4	33.4	23.4
CV	90	67.1	23.9	14.9
CVV	62	44.2	17.3	16.2
C-37-V	38	67.1	24.1	18.3
VSS	24	49.8	20.9	16.9
SEC	45	58.9	29.4	18.4
SECN	45	82.0	39.2	20.8

for the same hull designs would encourage the purchase of more of these vehicles, thus reducing the cost of each unit and increasing flexibility. Intraservice and interservice parochialisms aside, there seems to be no persuasive reason why the same platform could not fill the role of a carrier in one scenario and that of an LHA or even high-speed transport in the next.

CHAPTER V

AMPHIBIOUS WARFARE APPLICATIONS

It became obvious during design of the SEC and SECN that several factors argued for examination of other roles for large surface effect ships. First, with today's operating carriers scheduled for a service life extension program (SLEP), there should still be at least 12 operating carriers through the end of this century. The SEC would operate in addition to these decks, no matter the role it was given. Demands for high-speed amphibious vehicles may be more imminent than those for carriers, and the quantity required to fulfill some combination of the two missions, might drive the unit procurement cost downwards. The SEC could operate at 15-30 kt accompanying an ARG, then sprint ahead or from beach to beach at 50 kt as the mission demanded. Second, to obtain its speed and design endurance, an SEC is constrained to carrying only low-density cargo (e.g., vehicles and personnel). Just as the typical aircraft carrier loadout meets this criterion, so does that normally assigned to an amphibious vessel (e.g., LPH or LHA).

Given the above facts, additional factors were observed which would cause a surface effect platform to handle amphibious tasks in a unique fashion. The SEC would be ideally suited to operate future landing craft. By reducing

cushion pressure, the lower hangar deck could be brought within 2-3 m of the ocean surface, then landing craft could be embarked or debarked via ramps. The vehicles would need to be wheeled, tracked, or air cushion, such as the current LVTP-7 or the planned LVA and LCAC. Boats designed to operate from traditional well decks could not be accommodated. These adjustable ramps would also expedite dockside RO/RO cargo handling straight from the pier to either hangar deck.

Concept of Operations

Amphibious operations today range in size and intensity from assault through smaller raids, demonstrations, withdrawals and feints. Surface effect and air cushion/hovercraft technology may offer alternatives across this spectrum. The SEC could provide high speed loadout, transit to the objective area, and debarkation/withdrawal via landing craft and helos, as well as provide V/STOL air support.

Aircraft (CTOL and V/STOL, including helicopters) would be stored on the upper hangar decks with the elevators providing for movement between decks. Landing craft would occupy the lower hangar deck with other vehicles either inside the LCACs or parked on either deck. General cargo and POL in barrels could be stored along the sides of both decks between frames, with cargo nets and dunnage holding the containers in

place. Marine ordnance and bulk fuel would replace that supporting the air wing on the machinery deck and in voids.

Berthing for embarked Marines, besides that available from the air wing being off-loaded, could be attained by adding standard 8x8x20 containers, each equipped with 8 bunks and hung above vehicle parking on the hangar decks. A special framework would need to be constructed to support the containers and the walkways connecting them. Removal of these berthing containers would be required before the SEC could again accommodate its air wing.

Specific Requirements and Capabilities

To demonstrate the capabilities of an SEC/SECN in an amphibious role, three cases were selected and their generated requirements examined:

A: Rapid loadout of a notional MAU;

B: Deployment of a notional MAU;

C: Movement of the Assault Echelon of a MAF.

(Case A would not install extra berthing and support facilities). Approximate requirements for the notional MAU are shown in Table XVII and of the MAF in Table XVIII. To transport the MAF Assault Echelon would require 12 SECs.

Table XIV shows the requirements assumed in cases B and C for full berthing and support aboard. Table XV shows the available support per embarked V/STOL aircraft. There is more capacity in the SECN due to reduced need to store fuel.

TABLE XVII

APPROXIMATE "FINGERPRINTS" OF A NOTIONAL MAU

	WEIGHT (mT)	VOLUME (m^3)	DECK AREA (m^2)
Troops	450	30,000	---
Aircraft	91	---	1400
Vehicles	1500	---	3800
Cargo Fuel	2100	4,000	---
Craft	328	---	1800
Cargo Handling Equipment	100	---	---

TABLE XVIII

CRITICAL MAF ASSAULT ECHELON REQUIREMENTS

Troops	34,000 men
Vehicles	70,000 m^2
Cargo	40,000 m^3
Aircraft	360 units
Landing Craft	360 units (96 LCAC)

TABLE XIX

BERTHING AND SUPPORT REQUIREMENTS

For Each Marine: (Equipment, Food and 10 Days' Other Provisions)	.25 mT
(Berthing)	.3mT/4m^2/12m^3
LCAC: Weight	82 mT
Dimensions (Off-Cushion)	L=28 m B=13 m H= 6 m
Capacity	180 m^2

TABLE XX

REQUIRED/AVAILABLE CAPACITY PER V/STOL AIRCRAFT EMBARKED

	SEC	SECN
Airframe and Avionics	16 mT	16 mT
Ordnance	29 mT/37 m^3	39 mT/50 m^3
Fuel	59 mT/76 m^3	82 mT/107 m^3
Personnel (25/plane)	10 mT	10 mT
Equipment	7 mT	7 mT
Parking Space	210 m^2	210 m^2

Calculations were done using the SEC and SECN designs to examine the feasibility of quick deployment of a MAU, deployment of a MAU with full support, and embarking one-twelfth of an MAF Assault Echelon. In both the MAU cases, sufficient room is left to carry several (16 for the SECN and 12 for the SEC) V/STOL aircraft for protection and CAS with the men and equipment to support them. Both designs became weight limited as the load was increased, the SEC at 5450 mT capacity and the SECN at 7000 mT. Volume was not a critical constraint. Endurance for the SEC dropped from 6300 nm to 4700 nm as the load and ship's speed increased.

In summary, a comparison of the lift requirements of a MAU and the facilities and capabilities offered by SEC/SECN designs leads one to feel the two are compatible. As surface effect technologies are refined and a ship of this size appears feasible within acceptable risk, then a more detailed study should be undertaken to determine whether the benefits which now seem obvious can be realized.

CHAPTER VI

CONCLUSIONS AND SUMMATION

Within the scope of known technology and available resources, this study has shown that the concept of adapting SES technology to the carrier mission is feasible. Recently, our current 3K SES effort has died and been reborn. Only by pursuing this effort can we develop and prove the technology required to move forward beyond this point. It has been shown that two SEC/SECN designs can be procured for the price of a CVN and (after some assumptions) that surface effect ships provide some large benefits in this mission over the single large carrier. The following paragraphs highlight some of the unique characteristics of an SEC and some of the problems which may face its developers.

High speed, storage capabilities, and takeoff and landing procedures are the three differentiating qualities of the SEC. The speed of this craft permits it to cover greater ocean areas than is possible for slower displacement ships. To take advantage of this ability, an SEC task group must operate in a dispersed or open formation with 50 to 200 nautical miles between units. This will be examined in Part II. Its speed and bow ramp also allow aircraft to be launched with shorter takeoff runs, and greater safety.

Unfortunately, wind turbulence caused by high speed will require that all aircraft be stowed below decks. In order to satisfy this need, the SEC has two hangar decks, both serviced by the same three elevators. These dual hangar decks allow more flexibility in readying aircraft for the flight deck and for the amphibious option.

The final feature affecting operation is the Short Take-off and Vertical Landing (STOVL) mode employable by the V/STOL aircraft of the SEC. This mode will permit any aircraft greater range and payload with a rolling takeoff, while being able to land vertically for convenience, dispersion to escorts or in an emergency. Cross-decking between the carrier and her escorts should add to the ocean coverage of these units and the ability to concentrate air power at extreme distances from the carrier.

Hangar Deck Operation

Aircraft operating from the SEC will encounter several differences in comparison to a displacement hull carrier. Ordnance will be brought up to either hangar deck from magazines on the machinery deck by ordnance elevators. The ordnance will be moved to individual aircraft conventionally with skids. Fuel will be stored in cells within the deck structure and pumped to several fueling stations on each hangar level. These stations will be able to fuel every aircraft parked in the hangar area.

Aircraft are located on the hangar decks in either parking or ready spots. A clear transit lane will permit any aircraft to be transferred from a parking spot to a ready spot without disturbing any other parked aircraft. The universal handling vehicle (UHV) which operates like the existing spotting dolly, but has the power of present-day tractors, will move aircraft around hangar and flight decks.

Normal carrier level maintenance will be provided from containerized vans: fully equipped, air-conditioned work areas. These standard-size containers also provide for spare parts storage and can be secured to the bulkheads, two levels high along the edges of the hangar decks, where they will not interfere with aircraft spotting. One container will be allotted per aircraft embarked. Space for other equipment is available on hangar decks. Additionally, each aircraft is allotted 210 square meters for parking, a large margin over the 100-150 square meters required by current V/STOL designs.

Portals used for dockside loading of aircraft and RO/RO containers could also provide possible engine stand test firing locations. Selected portals would have to be suitably isolated from the rest of the hangar deck to prevent noise pollution and for fire protection.

Flight Deck Operations

Once on the flight deck, the aircraft is moved into one of three launch or four holding positions (see Chapter II).

Each position must be protected by a wind screen capable of reducing the wind velocity from up to 100 knots to about 15 knots, thus permitting personnel and equipment to prepare the aircraft for launch. Before a launch, the wind screen folds into the deck, allowing the aircraft to pass over it.

Even without a ramp, the three runways should provide sufficient roll for any V/STOL (50 kt or better headwind) to launch in the STO mode carrying maximum load. With the ramp, even an A-18 should be able to get airborne with a maximum load and a 60 kt headwind from all three launch points. Without the ramp, the port runway can launch an F-14 with maximum load into a 50 kt headwind. The catapult normally required to launch CTOL aircraft is uncessary due to the speed of the wind over deck and the ramp. Similarly, due to greater relative wind over deck, less fuel will be required for takeoffs and landings on the SEC than would be required on other carriers.

Conventional aircraft landings can be accommodated on the SEC. Two arresting wires are provided for conventional landing utilizing both the port and central runways. A crash crane is stored at flight deck level in the island for emergencies. Blast deflectors are provided for the center and starboard launch positions. Port launch positions are ready spots. This permits the exhaust blast of

the aircraft to go over the side or stern of the ship. All launch and ready locations have air-conditioning units and ships internal navigation cable hookups mounted in the deck.

The SEC can carry Tomahawk and Harpoon missiles as well as defensive AAW and ASW weapons. These weapons are limited in numbers and should only be considered as a last resort. The air wing is the principle weapon of the SEC and its task group against air, surface and subsurface targets.

Problem Areas

The most serious problem confronted during this study effort was the volume-related overall height limitation, which makes the design of a structural framework more difficult. The danger is that the problem may not be solvable by engineering without requiring a significant increase in system weight. However, volume has been defined by the least precise relations in this study, and requirements are probably overestimated.

A second concern is the development of propulsion systems that can deliver propulsive efficiencies within 5% of the 68% assumed in this study. Range is nearly proportional to propulsive efficiency. Speed is less affected. Again, these reductions can be made up by increasing the SEC cost and weight. The SECN will feel only a speed reduction to compensate for any lowering propulsive efficiency. The range

reduction will be felt over its life span, not while performing a given task.

In addition to the benefits a lightweight nuclear plant would provide as a hedge against not attaining higher propulsion efficiencies, its other benefits are many. On SECs this large, gas turbine designs can carry sufficient fuel for high endurance. However, examinations of smaller designs show that retaining transoceanic endurance becomes more and more difficult as the system weight decreases. Lightweight nuclear systems (providing 130-150 mhp/mT, compared to the 30-60 mhp/mT of current nuclear plants) would lend themselves to SES designs over a wide range of sizes and at higher speeds than specified for the SECN. Nuclear power will reduce the dependence of surface effect ships on slower, displacement hull replenishment units and provide more weight and volume for payload whether it be in the combat suite, air wing, or embarked Marines. Its development will provide the capability for task groups of surface effect ships to leave CONUS and transit at 50 kt anywhere in the world they may be required. The combination of LWNP with the SES technology may change naval warfare to the same extent that heavier nuclear plants changed tactical and strategic submarine warfare two decades ago.

Other problems encountered in the study are the kind that engineers and naval architects should be able to solve with normal research and development expenditures. This

conclusion will be weakened if the present SES Project of the Navy is scrapped. Much of the technology required by the SEC is incorporated in the Rohr SES design and can only be evaluated by putting that vehicle into an ocean environment.

One problem with the SEC has not previously been mentioned, for its effect was not quantifiable. This problem concerns platform motion at sea and its effect on aircraft operations and handling. Speed creates motion problems; size diminishes them. The SEC will probably not have the heave difficulties of the present SES, but may have an adverse rolling motion. Whether this concern is valid and correctible is worth investigation.

Reflections

The concept of a 50 kt carrier is heady stuff to contemplate. The possibility of having two of these vehicles for every CVN means the Navy could continue to be a policy instrument on a global scale. Transit times for SECN would be 40% less than a present nuclear task group with the same infinite range. Two SECs could transit 6000 nautical miles at over three times the speed of a CV and use less than twice the fuel. The SEC or the SECN could convert to an amphibious ship without altering its basic structure. This feature could swell the total number of these vehicles in the inventory permitting greater flexibility. The Surface Effect Carrier is affordable and whether nuclear or not, the concept appears to be worth greater study by the Navy.

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SURFACE EFFECT CARRIER (SEC) STUDY. PART I. PLATFORM DESIGN.(U)
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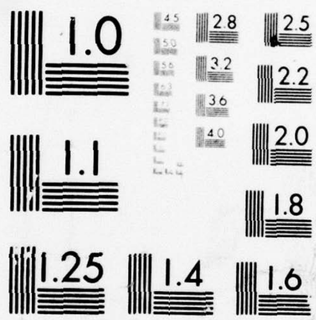

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Chapter III

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